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WEEKLY March 28–April 3, 2020

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- *How the virus transmits*
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This week's issue

On the cover

44 Reset your immune age
How getting older makes you more prone to infections – and what you can do about it

34 Inside quantum collapse
Have we finally seen reality in the making?

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RESET YOUR IMMUNE AGE

How getting older makes you more prone to infections – and what you can do about it

INSIDE QUANTUM COLLAPSE

Have we finally seen reality in the making?

Coronavirus
10 How the virus transmits
9 Criticism of UK strategy
8 Most promising treatments
10 Questions around immunity
20 Why the US is so vulnerable

12 World's highest mammal 15 Ancient Roman lapdog
51 Perfect pastry 16 Mystery penguin sounds 14 Tiny meteorite

Vol 245 No 3275
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Coming next week

Becoming human
Rewriting the epic story of our species' ancient origins

News

12 Mighty mouse
Meet the mammal that thrives atop a Mars-like volcano

14 Our intertwined story
Diverse genetic analysis reveals our hidden history

16 Sweet sensation
Our guts may be able to distinguish between sugar and low-calorie sweeteners

Views

23 Comment
Coronavirus policies must account for factors other than just science, says David Adam

24 The columnist
Chanda Prescod-Weinstein on the Hubble constant

26 Letters
The effects of the pandemic across the social gradient

28 Aperture
Meet the sea creature named in the fight against plastic

30 Culture
Evolution's bones laid bare

JENNY EVANS/GETTY IMAGES; TOP: THE NATURAL HISTORY MUSEUM/ALAMY

7 Coronavirus crowds Many have been disregarding social distancing advice, but a fifth of the world is now on lockdown

34 Features

> "The idea that quantum measurement involves an almost magical transformation is dead"

Features

34 Inside quantum collapse
Solving the mystery of how reality gets made

40 Friendship apps
How well can new technology help us manage our personal relationships?

44 Change your immune age
Keeping your immune system young could be more important than ever

The back pages

51 Science of cooking
Become a pastry whizz

52 Puzzles
Quick crossword, a change challenge and the quiz

53 Feedback
Odd social distancing tips and the rise of the bidet: the week in weird

54 *Almost* the last word
Sleep trackers and the seat of wisdom: readers respond

56 The Q&A
John Troyer on technology and dead bodies

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A strange new world

The new coronavirus may be upending our lives, but we aren't helpless against it

HARD times lie ahead. Not only do we all have to contend with the threat of covid-19 itself, and its economic fallout, but as nations lock down movement outside our homes, there are extra mental pressures to cope with too.

Fortunately, there are constructive things we can do. Our individual actions can slow the spread of the virus. We can help our neighbours to get through this. We can reach out electronically to support others. Such actions may help us develop a new sense of togetherness, and that will help.

There is something else, though, that we can do to improve both our physical and mental resilience: exercise. As we report on page 44, exercise is a sure-fire route to a stronger immune system.

This isn't your typical well-being advice, issued alongside adjuncts to eat and sleep well. This is grounded in the cutting-edge science behind the idea that our immune system has an age that doesn't necessarily match our body's count in years. As we discuss, exercise is just one part of what we can do to reduce our immune age and strengthen our body's defences against disease.

> "Exercise is just one part of what we can do to strengthen our body's defences against disease"

Elsewhere in this issue, we look at the race to identify and test drugs that might treat covid-19 (page 8). Caution is needed: many celebratory reports and announcements are premature, and we are still without a drug that can help those who are seriously ill.

We also analyse the scientific advice that informed the UK government's coronavirus strategy (page 9), which until Monday night was notably different from the line many other countries were taking, and report on studies showing that the virus causes negligible symptoms in many of those who have it. Strangely, infectiousness seems to peak before the onset of noticeable symptoms (page 10).

In the longer term, the question of immunity is going to be a central one (page 10). Will we be immune to the covid-19 virus if we get and recover from the illness or are we looking at wave after wave of infection? Despite the huge amount of science under way, there are many questions still in urgent need of answers. ▮

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New York City went into lockdown on Sunday to slow down the virus

World in lockdown

Around a fifth of the global population is in lockdown as covid-19 cases continue to rise, reports **Jessica Hamzelou**

THE covid-19 pandemic is speeding up, the World Health Organization's director general has warned. As *New Scientist* went to press, 382,000 cases of the disease had been confirmed, although the actual number is likely to be much higher. More than 16,500 people have died.

"It took 67 days from the first reported case to reach the first 100,000 cases, 11 days for the second 100,000 cases and just four days for the third 100,000 cases," Tedros Adhanom Ghebreyesus told journalists at a press briefing on Monday. "The virus is accelerating."

On the same day, the UK government announced that everyone should stay at home, leaving the house only for basic necessities like food and medicine, to meet the medical needs of themselves or others, to travel to and from work if necessary and for one form of exercise per day. For at least the next three weeks, non-essential shops and venues will be closed and public gatherings of more than two people are banned. Those who don't comply face fines or dispersal by the police.

While Hubei province in China, where the outbreak started, plans to lift its travel restrictions, a similar lockdown came into effect in New York City on Sunday, when New York state accounted for half of the confirmed US covid-19 cases.

On Monday, South Africa's president, Cyril Ramaphosa, announced a 21-day national lockdown, set to begin on 26 March. On Tuesday, India reported 519 confirmed cases and 10 deaths. It has imposed a three-week lockdown on its 1.3 billion people.

Strict measures do seem to slow the spread of infection. A team in Singapore has used modelling to show that measures including isolating infected people and quarantining their relatives, closing schools and encouraging people to work from home would significantly reduce the number of infections. Assuming a starting point of 100 infected people, these measures would cut the number of cases by 99.3 per cent over an 80-day period in Singapore, the model found (*The Lancet Infectious Diseases*, doi.org/dqfh).

These measures could ease the strain on health services by slowing the outbreak, but the only way to truly control outbreaks is to test suspected cases, properly isolate them and trace all of the people they have come into contact with, the WHO's director general has repeatedly said.

Despite this, the approach to testing suspected cases varies wildly between countries. The UK is still only testing people who are hospitalised. It is reported that just nine of the 2700 passengers that disembarked the Princess Ruby cruise ship in Sydney on 8 March were tested, despite reports of 158 passengers feeling unwell while onboard. Since then, 133 of the passengers have tested positive for covid-19, and one person has died.

In the meantime, researchers are starting to learn more about the virus, how it infects us and who is vulnerable (see page 10). Until 22 January, only one case of infection had been reported in children in mainland China. A 24 February report covering 44,672 cases found that children under the age of 10 made up less than 1 per cent of cases and no deaths (*JAMA*, doi.org/ggmq43).

Since then, more cases of children hospitalised with the infection have come to light. Based on reports from a handful of hospitals in China, one team estimates that, by 22 January, around 1105 children were receiving hospital treatment for covid-19 in the city of Wuhan alone (medRxiv, doi.org/dqfg). If there were this many severe cases, tens of thousands of children were likely to have had mild cases, the authors say. ▮

Coronavirus daily update
The latest news, every weekday at 6pm GMT
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Treatments

Drug search continues

There has been much enthusiasm for promising medicines, but it is unclear if any will help those who really need them, reports **Michael Le Page**

DESPITE what you may have heard, although several potential drugs for covid-19 are being trialled around the world, few results have been reported yet, and we don't know if any could help save people who are already seriously ill when diagnosed.

Some enthusiastic news stories and claims being spread on social media are based on little more than anecdotal reports. However, the World Health Organization (WHO) is coordinating an international trial of the most promising drugs – and with case numbers soaring, we should find out soon if any of them work.

"This trial focuses on the key priority questions for public health. Do any of these drugs reduce the mortality? Do any of these drugs reduce the time the patient is in hospital? And whether or not the patients receiving any of the drugs needed ventilation or an intensive care unit," said Ana Maria Henao-Restrepo of the WHO at a briefing on 18 March.

The WHO trial will include the long-used antimalarial drugs chloroquine and hydroxychloroquine, a new antiviral drug called remdesivir and a combination of two HIV drugs called lopinavir and ritonavir. The HIV drugs will also be tested in combination with an antiviral called interferon beta.

"What we need most is a drug that can save lives when covid-19 is identified in severe cases"

On 22 March, several countries in Europe, including the UK, launched a collaborative trial of the same drugs, which will complement the WHO effort.

There has been a tremendous buzz about chloroquine after it was highlighted first by entrepreneur Elon Musk and then US president Donald Trump, who wrongly claimed it was already approved in the US for treating covid-19.

PATRICK SEMANSKY/AP/SHUTTERSTOCK

US president Donald Trump was wrong about the drug chloroquine

There is some evidence that chloroquine and the closely related hydroxychloroquine are effective against related viruses such as the one that causes SARS. There have also been reports from China that chloroquine is beneficial when given to people with covid-19 associated pneumonia, but the findings have yet to be published. "It looks promising," says Robin May at the University of Birmingham, UK.

However, some excitement over these drugs stems from a study of just 42 people in France that said those who received hydroxychloroquine cleared the coronavirus from their bodies days faster, with the effect being even greater in those also given the antibiotic azithromycin (medRxiv, doi.org/dqbv).

The researchers speculated that hydroxychloroquine can prevent infection as well, but other researchers say the small size of the study and other issues mean we can't rely on its results.

What's more, while hydroxychloroquine and chloroquine are safe when taken properly, there are already reports of people overdosing on chloroquine in an attempt to protect themselves, which can cause lethal heart problems.

Meanwhile, people who need this drug for lupus or arthritis are finding it hard to get hold of.

Hunting for antibodies

Even if chloroquine does stop people becoming severely ill if given when symptoms are still mild, it wouldn't necessarily be a game changer. At the moment, most countries are detecting coronavirus infections only once people develop severe symptoms, so what we urgently need is a drug that can save lives at this stage. "Whether that's going to crop up is anyone's guess," says May.

Unfortunately, it already seems that the lopinavir and ritonavir combination doesn't do this. A randomised trial in China found no evidence of any benefit (*NEJM*, doi.org/ggpcms). As for remdesivir, the results of trials in China haven't been made public yet.

Many other potential treatments are being explored, particularly the possibility of developing antibodies against covid-19. Antibodies are the proteins our immune systems use to kill the virus, but it takes weeks for our bodies to ramp up production after we are infected.

In theory, injecting antibodies made in a factory should be an effective way to both prevent and treat covid-19. US company Regeneron says it has already identified hundreds of antibodies against the coronavirus and plans to start mass-producing the most potent ones in mid-April.

Another way to get antibodies is to extract them from the blood of people who have recovered from covid-19. At least 250 people in China have received treatments made this way. According to the Xinhua news agency, it was safe and effective, but the findings don't yet appear to have been published.

All the approaches described above are based on trying to kill the virus or prevent it replicating. However, it appears that most deaths from covid-19 are the result of a severe immune reaction called a cytokine storm. So another path is finding ways to prevent or dampen this response. A small study in only 19 people suggests that an immunosuppressive antibody called tocilizumab is highly effective (ChinaXiv, DOI: 10.12074/202003.00026).

This approach can be risky, though. "Immunotherapy is really challenging because you're messing with the immune system of people who are very sick," says May. ▮

A cause for concern The UK government has released the scientific advice it has received on covid-19, and independent experts aren't impressed, reports **Jessica Hamzelou**

AS THE covid-19 pandemic rages on, governments are turning to teams of scientists for guidance on how to proceed. On 20 March, the UK government finally published the scientific advice it had received.

At first, most commentators welcomed the transparency. But closer reading of the documents made available online suggests a few causes for concern. The strongest advice from the World Health Organization (WHO) on controlling outbreaks of the coronavirus – abundant testing – barely gets a mention, for example. And the guidance seems to lean heavily on a single model of the outbreak, one that some scientists suggest contains systematic errors.

The UK government is advised by a panel of epidemiologists, infectious disease modellers, virologists, medical doctors and groups that focus on pandemic influenzas. The exact members vary, a government representative told *New Scientist*.

The dozen reports compiled by this panel summarise what is known about the virus and its spread, and the likely impact of any government measures taken to prevent it. Social distancing comes up several times, but there is barely a mention of widespread testing, despite the WHO director-general's pleas to all countries to "test, test, test".

As the WHO's assistant director-general Bruce Aylward told *New Scientist* last week, the countries that are best able to control outbreaks of the virus are those extensively testing people who might be infected, isolating them away from their friends and relatives and tracing who they have been in contact with. The UK guidance doesn't mention this.

"I think it is incredibly surprising that testing and contact-tracing is overlooked," says Devi Sridhar at the University of Edinburgh in the UK. "Outbreaks begin and end with testing."

The reports draw heavily on models of how the outbreak will develop with various interventions. These models all come from one team, based at Imperial College London. "It comes across as though they have based everything on the Imperial model," says Paul Hunter at the University of East Anglia, UK.

Chen Shen at the New England Complex Systems Institute in Cambridge, Massachusetts, and his colleagues argue that the Imperial team's model is flawed, and contains "incorrect assumptions". They point out that the Imperial team's model doesn't account for the availability of tests, or the possibility of "super-spreader events" at gatherings, and has other issues.

No model will be perfect. "To be fair, the Imperial people are the some of the best infectious disease modellers on the planet," says Hunter. "But it is risky to put all your eggs in a single basket."

Ideally, the government should incorporate the results of at least two different teams of infectious disease modellers, says Hunter.

Other aspects of the scientific advice to the government appear to have gone unheeded until recently. A report compiled by the advisers on 4 March, for example, warns that school closures are only effective if children also practice social distancing, and highlights the need to consider knock-on effects of social distancing, such as crowded parks and queues for takeaways.

But, as photographs taken at public parks and beaches last weekend show, the government failed to prevent this type of crowding, which can provide the ideal conditions for the virus to spread.

52%

Proportion of UK adults avoiding crowded areas (17-18 March)

Stricter restrictions on movement were announced on 23 March. Before then, there appeared to be plenty of confusion among members of the public. A survey of 2108 UK adults, conducted on 17 and 18 March, found that only 52 per cent of people said they were avoiding crowded areas.

Only half of survey respondents said they were avoiding social events, and just 36 per cent were avoiding public transport. Although 71 per cent of adults said they had changed their behaviour in some way based on government advice, only 53 per cent of young adults aged 18 to 24 had.

This explains why stronger measures are now in place in the UK, requiring most people to stay at home else risk fines or dispersal.

Part of the problem is that communications from the government haven't been clear enough, says Hunter. One way to clarify would be to swap the use of vague terms like "social distancing" with clear advice, such as to keep a physical, 2-metre distance between yourself and others.

"It is difficult to keep up with the advice," he says. "The advice from the government has changed, usually for good reasons, but this generates confusion in people – even in me." ▮

London's Clapham Common showed few signs of social distancing on 22 March

PETER SUMMERS/GETTY IMAGES

Infection rates

Infectious without symptoms

It is easy to spread the virus without realising you are ill, reports **Graham Lawton**

WITH more than 380,000 confirmed cases worldwide, one thing is clear about the new coronavirus: it is very good at infecting people. Now studies are starting to reveal just how infectious it is – and when a person with covid-19 is most likely to spread the virus.

While we know some people are more vulnerable to the virus than others, it is capable of putting a healthy adult of any age into a critical condition and in need of intensive care. However, the virus can also be asymptomatic, causing no noticeable illness in some people. Such cases were first recognised in China in January (*Science China Life Sciences*, doi.org/dqbn), but it wasn't known how common they were.

Research published last week by Jeffrey Shaman of Columbia University in New York and his colleagues analysed the course of the epidemic in 375 Chinese cities between 10 January, when the epidemic took off, and 23 January, when containment measures such as travel restrictions were imposed.

The study concluded that 86 per cent of cases were "undocumented" – that is, asymptomatic or had only very mild symptoms (*Science*, doi.org/ggn6c2). The researchers also analysed case data from foreign nationals who were evacuated from the city of Wuhan, where the first cases were seen, and found a similar proportion of asymptomatic or very mild cases.

Such undocumented cases are still contagious and the study found them to be the source of most of the virus's spread in China before the restrictions came in. Even though these people were only 55 per cent as contagious as people with symptoms, the study found that they were the source of 79 per cent of further infections, due to there being more of them, and the higher likelihood that they were out and about.

"If somebody's experiencing mild symptoms, and I think most of us can relate to this, we're still going to go about our day," says Shaman. "These people are the major driver of it and they're the ones who facilitated the spread."

A project in Italy has also found many symptomless cases. When everybody was tested in a town called Vò, one of the hardest-hit in the country, 60 per cent of people who tested positive were found to have no symptoms.

That is lower than the number found in China but is in the same ballpark, says Shaman. "It might be one in 10 in some societies versus one in five in others, but generally you're looking at about an order of magnitude more cases than have been confirmed," he says.

For most people who do fall ill, symptoms are usually mild and develop slowly, according to the US Centers for Disease Control and Prevention. While many have heard that a cough, fever, shortness of breath and fatigue can be signs of covid-19, the condition's symptoms can also include a runny or stuffy nose, sore throat, headache, muscle pain, diarrhoea, nausea and vomiting.

Of those who get ill, 19 per cent enter a severe or critical condition,

CHRIS J RATCLIFFE/GETTY IMAGES

Covid-19 may largely be spread by people with barely any symptoms

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Immunity

Do you become immune once you have been infected?

SAY you have caught covid-19 and recovered – are you now immune for life, or could you catch it again? We just don't know yet.

In February, reports emerged of a woman in Japan who had been given the all-clear after having covid-19 but then tested positive for the SARS-CoV-2 virus a second time. There have also been reports of a man in Japan testing positive after being given the all-clear, and anecdotal cases of second positives have emerged from China, too.

This has raised fears that people may not develop immunity to the virus. This would mean that, until we have an effective vaccine, we could all experience repeated rounds of infection.

But the science is still uncertain. "There is some anecdotal evidence of reinfections, but we really don't know," says Ira Longini at the University of Florida. It may be that the tests used were unreliable, which is a problem with tests for other respiratory viruses, says Jeffrey Shaman at Columbia University in New York.

Early signs from small animal experiments are reassuring. A team from the Chinese Academy of Medical Sciences in Beijing exposed four rhesus macaques to the virus. A week later, all four were ill with covid-19-like symptoms and had high virus loads. Two weeks later, the macaques had recovered and were confirmed to have antibodies to the virus in their bloodstream.

The researchers then tried to reinfect two of them but failed, which suggests the animals were immune (bioRxiv, doi.org/ggn8r8). "That finding is very encouraging, as it suggests that it is possible to induce protective immunity against the virus," says Alfredo Garzino-Demo at the University of Maryland School of Medicine.

But that doesn't necessarily mean long-term immunity. There are other coronaviruses circulating

> "You can be infected with other coronaviruses over and over. We don't know if that's true for this virus"

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usually with pneumonia. The mortality rate varies depending on a number of factors, such as a population's average age, the state of a country's healthcare system and the extent to which mild cases are identified and counted. A study last week estimated that 1.4 per cent of symptomatic cases in Wuhan died (*Nature Medicine*, doi.org/dqbq).

It is rarer for children to develop serious disease, but it is a myth that young, healthy adults don't. "There are some young people who have ended up in intensive care," said the UK government's chief medical adviser, Chris Whitty, at a briefing on 19 March.

Once someone is infected, the incubation period is usually between two and 14 days, with half of cases showing symptoms before the sixth day (*Annals of Internal Medicine*, doi.org/dph3). However, this was calculated by studying 181 confirmed cases, meaning it is unlikely to have taken very mild and asymptomatic cases into account.

Even people who develop symptoms are at risk of unwittingly spreading the virus. A study in China suggests that infectiousness starts about 2.5 days before the onset of symptoms, and peaks 15 hours before (medRxiv, doi.org/dqbr).

We know that coughs and sneezes spread the virus, so how is it possible for asymptomatic people to spread the infection?

People with mild or no symptoms can have a very high viral load in their upper respiratory tracts, meaning they can shed the virus through spitting, touching their mouths or noses and then a surface, or possibly talking. Even people who don't feel ill occasionally cough or sneeze.

Once symptoms develop, a person's viral load declines steadily, and they become increasingly less infectious. However, people appear to keep shedding the virus for around two weeks after they recover from covid-19, both in their saliva and stools (medRxiv, doi.org/dqbs). This means that even once a person's symptoms have cleared, it may still be possible to infect other people.

86%
This proportion of cases in China had no or very mild symptoms

14 days
An infected person may take this long to develop any symptoms

15 hours
People who have symptoms are most contagious this many hours before the symptoms begin

Airborne droplets are likely to be the main infection route, but contaminated surfaces could play a role too. Health advice typically says the virus can persist for about 2 hours on surfaces, says William Keevil at the University of Southampton, UK.

But a study published last week suggests that this is a serious underestimate, with viable virus surviving on cardboard for 14 hours and plastic and stainless steel for up to three days (*New England Journal of Medicine*, doi.org/ggn88w). It can also hang around in the air for at least 3 hours.

"Survival of coronaviruses for days on touch surfaces is a hygiene risk," says Keevil. "It is difficult to avoid touching [contaminated objects or surfaces] such as door handles and push plates, bed and stair rails, public touch screens etc."

There is also some evidence of transmission from faeces to the mouth, says Elizabeth Halloran at the University of Washington, which reinforces the importance of handwashing.

Keevil recommends regular, rigorous handwashing or using an alcohol hand gel, and avoiding touching the eyes, nose and mouth. "The latter being extremely difficult because humans are tactile and touch their faces many times an hour," he says.

What all this makes clear is that advising only people with a cough or fever and their families to self-isolate won't prevent the coronavirus from spreading, thanks to its fiendish ability to cause very mild symptoms in people, and to peak in infectiousness before people even realise they are sick. ▮

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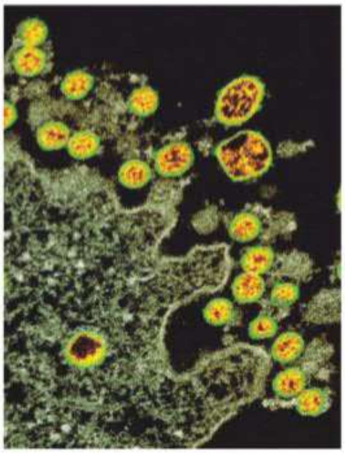
among humans and although they induce immunity, this doesn't last. "Some other viruses in the coronavirus family, such as those that cause common colds, tend to induce immunity that is relatively short-lived, at around three months," says Peter Openshaw at Imperial College London.

"Because [the virus] is so new, we do not yet know how long any protection generated through infection will last. We urgently need more research looking at the immune responses of people who have recovered from infection to be sure," says Openshaw.



CDC/SCIENCE PHOTO LIBRARY

SARS-CoV-2 virus particles (yellow), as seen using an electron microscope

Other immunologists agree. "Immunity to SARS-CoV-2 is not yet well understood and we do not know how protective the antibody response will be in the long-term," says Erica Bickerton at the Pirbright Institute in the UK.

"For ordinary coronavirus infections, you do not get lasting immunity," says Longini. "You can be infected over and over, and we really don't know for this novel coronavirus if that's also true."

Other infectious disease specialists are more optimistic. "The evidence is increasingly convincing that infection with SARS-CoV-2 leads to an antibody response that is protective. Most likely this protection is for life," says Martin Hibberd at the London School of Hygiene & Tropical Medicine. "Although we need more evidence to be sure of this, people who have recovered are unlikely to be infected with SARS-CoV-2 again." ▮ GL

Solar system

Strange lines on Venus's surface may be stacks of lava

Leah Crane

THE surface of Venus, which is often considered dead and inactive, is covered in weird lines that suggest some kind of active erosion.

These lines, called tesserae, cover about 7 per cent of the planet. They were spotted by Russian Venera orbiters in the early 1980s and are characterised by long, parallel lines on hills and mountains that look like the ground has folded over itself.

Paul Byrne at North Carolina State University and his colleagues examined the few radar images we have of Venus's surface to try to figure out what these tesserae are. They noticed that the lines tend to curve along features on the ground, similar to a topographical map, rather than simply cutting across.

> "There has been wind planing off sediment and carving these weirdo terrains"

"If you imagine getting a phone book and then you take a chainsaw and carve topography into it, when you look down on that book that you've now butchered, you see this complicated curving pattern of those sheets of paper," says Byrne. That is similar to the pattern of the tesserae, and indicates that they are made of some sort of layered rock.

Byrne and his colleagues suspect that some of these layers may be sheets of lava folded into stacks. Regardless of whether it is a stack of lava or simply sedimentary rock, they found that something must be wearing down the surface to expose the sides of the layers.

"For us to see these lines in this curving pattern, there must be erosion," says Byrne, who was due to present the work at the cancelled Lunar and Planetary Science Conference in Texas. "In the last few hundred million years, there has been wind planing off sediment and carving these weirdo terrains." ▮

Zoology

The world's highest-living mammal

Colin Barras

GERARD PRINS/GETTY IMAGES; RIGHT: MARCIAL QUIROGA-CARMONA

This mouse somehow lives on Llullaillaco (left), an Andean volcano

AT THE summit of Llullaillaco, a volcano in the Andes that rises 6739 metres above sea level, lives a mouse.

Not just any mouse – it is the highest dwelling mammal in the world – and how it survives in an environment so hostile that it has been compared to Mars has left scientists baffled.

Life isn't easy at the top of Llullaillaco, which is on the border of Chile and Argentina. The average temperature is -15°C and the air pressure is so low that there is less than half as much oxygen in each lungful of air as at sea level.

Humans can't survive for long at the peak. In 1999, archaeologists uncovered the frozen and perfectly preserved mummies of three Inca children who had been drugged and left to die on the summit 500 years ago, as part of a ritual sacrifice. But the yellow-rumped leaf-eared mouse (*Phyllotis xanthopygus*) apparently thrives there.

Mountaineers have reported seeing mice near the top of Llullaillaco, so last month an international team of biologists journeyed to the Andes to investigate. The team, led by Jay Storz at the University of Nebraska and Guillermo D'Elía at the Austral University of Chile, spent weeks studying mice at a range of elevations before Storz and a colleague journeyed to the peak of Llullaillaco, where they spotted and trapped a mouse (bioRxiv, doi.org/dp5d).

The altitude meant the researchers struggled to get enough oxygen. "I felt like I was staggering around up there," says Storz. "But the mouse didn't seem too impaired."

What makes the fact that mice are so active on the volcano's peak even more astonishing is that they are so small. "They lose heat so much more easily because they have a higher surface-area-to-volume ratio," says Graham Scott at McMaster University in Canada. "They're having to generate lots of body heat to keep warm, but they're doing it even though there is very little oxygen available."

6739m

The height above sea level of the summit of Llullaillaco

This suggests the mice must have a voracious appetite to gain the energy they need to survive. That puzzles biologists because there are no green plants growing anywhere near the summit, making exactly what the mice eat a mystery.

"The summit is more than 2000 metres above the limits of green plants," says Storz. He thinks the mice might survive at least in part on insects, but more clues will come in the months ahead when the researchers analyse the mouse's gut contents.

Astrobiologists have previously drawn parallels between the conditions on Llullaillaco and those on other worlds including Mars in terms of temperature, aridity and exposure to ultraviolet light. "It's not the moon, but Llullaillaco is definitely not a place productive enough and hospitable enough that we would expect a mammal to live there," says Scott.

Some birds can briefly survive at even greater altitudes: geese migrating over the Himalayas reportedly reach heights above 7200 metres, says Grant McClelland, also at McMaster University. But the mice on Llullaillaco may spend their entire lives above 6700 metres. "It certainly changes our idea of the limits of where mammals can live," he says. ▮

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Human genetics

Ancient lineages intertwined

DNA analysis of people around the world reveals a more complex human story

Layal Liverpool

ANCIENT human populations in Africa probably mixed far more than we previously thought. That is just one of the revelations about our genetic history uncovered by sequencing the genomes of people from populations that have been under-represented in human genetic studies.

"We identified a lot of genetic variation that had not been found before," says Anders Bergström at the Wellcome Sanger Institute in Hinxton, UK.

Bergström and his colleagues sequenced the genomes of 929 people from 54 populations across the globe, including from Europe, the Middle East, Africa, the Americas, Central and South Asia, East Asia and Oceania. They discovered hundreds of thousands of new gene variants that had previously been missed in existing data sets (*Science*, doi.org/dp6n).

One discovery that Bergström and his colleagues made was that there was probably much more mixing between different ancient human populations in Africa than suggested by previous studies. Rather than a diverging family tree, they found evidence for gene flow between different populations. "It's more like a kind of intertangled mesh of branches," says Bergström.

This hints at how ancient humans migrated out of Africa. Rather than a population separating into two and each part never seeing the other again, people probably continued to move between groups in a more complex way, he says.

The team also found more detailed evidence of our ancient human ancestors mating with other hominins. We already knew that our ancestors mated with archaic human groups, including Neanderthals and Denisovans, but until now it wasn't clear how frequently this occurred or whether they mated with some groups more than others.

Bergström and his team were able to show that people from many different populations around the world today have the same segments of Neanderthal DNA in their genomes, but segments of Denisovan DNA differ between people in different populations. That suggests that our species probably mated with a single Neanderthal group but with multiple Denisovans after migrating out of Africa.

Genome studies so far haven't covered a very wide diversity of populations

JEFF OVERS/GETTY IMAGES

Analysis of the new data, which included whole genome sequences from people with Native American ancestry, also hints that there may have been many more early humans in the Americas about 15,000 years ago than previously thought.

"Our current genetic studies and infrastructure are vastly Eurocentric," says Alicia Martin at the Broad Institute in Massachusetts. "To ensure equitable translation of genetic technologies and to better understand human history and anthropology, we need the breadth of human diversity to be represented in our studies."

These findings also show that there is a lot more uncatalogued genetic variation out there across populations, including many gene variants that may be associated with disease, says Martin. ■

Space

Tiny meteorite could teach us how life's building blocks form

A MINUSCULE meteorite unlike any other we have discovered could help us understand the kinds of rocks that fill our solar system.

Maitrayee Bose at Arizona State University and her colleagues analysed the chemicals in a 2-millimetre meteorite found in Antarctica, called TAM19B-7. When they looked at the different carbon isotopes in the micrometeorite, they were in for a surprise.

"Some of the areas in the micrometeorite have the exact same composition as Earth," says Bose. "But there were some regions that were carbon-13-rich hotspots, which is something that we didn't expect to find at all."

The team spotted four of these little pockets of heavy carbon. The research was to have been presented at the now-cancelled Lunar and Planetary Science Conference in Texas.

The oxygen levels in the micrometeorite didn't match any known asteroid. It is usually possible to match a micrometeorite to the asteroid family it belongs to, although not with this sample.

But we know its parent rock contained frozen water because of the abundance of other isotopes in the micrometeorite, primarily those of oxygen, says Bose.

"Some regions were rich in heavy carbon, which is something that we didn't expect to find at all"

"It comes from a body that has lots of ice, and when that ice melts it interacts with the rock," she says. "The question is: can you make important, life-critical compounds by this interaction with water?"

On Earth, reactions between water and rocks can form sugars, amino acids and other chemicals important for life. Finding the micrometeorite's mysterious parent could help us figure out if similar activity can occur on asteroids. ■

Leah Crane

Animals

Well-travelled lapdog hints at Roman pet trade

Colin Barras

AN ARCHAEOLOGICAL excavation in southern Spain has uncovered the 2000-year-old remains of a lapdog that may have been born thousands of kilometres away. Its discovery hints at a long-distance trade in lapdogs across the Roman world.

Rafael Martinez Sánchez at the University of Granada, Spain, and his colleagues found a lapdog skeleton buried in a Roman cemetery in southern Spain. It was about 22.5 centimetres tall at the shoulder and had a small skull with large eyes, rather like a modern Pekinese.

Wear on the dog's teeth shows that it was an adult that was probably between 2 and 4 years old when it died. Fetal bones found inside the skeleton suggest that the lapdog was a female and was pregnant when she died.

An analysis of the lapdog's bones and teeth revealed that she may not have been local. The carbon and oxygen isotopes in bones provide information on the environment an animal's food and water came from, and the lapdog's bones suggest she grew up drinking water far away from the Atlantic.

This means she probably wasn't born in southern Spain but somewhere to the east, says Martinez Sánchez, perhaps Italy or the eastern Mediterranean. Two larger dogs buried in the same cemetery lacked this chemical signal and seem to have been born and raised locally (*Archaeological and Anthropological Sciences*, doi.org/dp5g).

"This animal had a life significantly different from that of the other animals found in the necropolis," says Martinez Sánchez. Its exotic origins might even hint at long-distance trade of small dogs in the Roman world, the researchers say. But this didn't save her from a grizzly end. A fractured neck bone indicates she may have been killed following her owner's death. ▮

Neuroscience

Brain implant kicks in as Parkinson's gets worse

Clare Wilson

VINCENT MONCORGE/LOOK AT SCIENCES/SPLY

PEOPLE with Parkinson's disease are getting brain implants that can automatically detect and reduce harmful nerve cell activity. Researchers are testing the devices to see if they can improve the movement difficulties that people with the condition have, while reducing the side effects the conventional form of this invasive treatment can lead to.

Parkinson's disease causes worsening tremors and difficulties with movement, especially when initiating actions. Medication can help, but as symptoms progress, some people undergo a more invasive treatment, called deep brain stimulation (DBS).

This works by placing wires into the skull that deliver a current to dampen down the activity in clusters of nerve cells in the centre of the brain. Unfortunately, it can cause side effects such as speech difficulties and jerky movements.

It may be possible to minimise these side effects by delivering stimulation only when it is needed, known as responsive stimulation. A similar kind of brain implant is already used in a few people with severe epilepsy that is unresponsive to medicines or surgery, to reduce the excessive nerve cell activity that causes seizures. But in people with Parkinson's, it is less clear what kind of brain activity causes the different symptoms and side effects.

One area of interest is the nerve cell clusters deep in the brain targeted by the implants. In most people, these centres sometimes fire in synchronous patterns called beta waves to signal that we should continue our present behaviour.

13

The number of people in the experimental brain implant trial

"It promotes the status quo," says Peter Brown at the University of Oxford.

In Parkinson's, there is an excess of beta waves, and this could explain why people with the condition sometimes move more slowly than they want to and have difficulties initiating new movements. So Brown and his colleagues are trying to stimulate the nerve cell clusters only when beta waves are detected.

Standard implants deliver constant electrical stimulation

The team tried the technique in 13 people with Parkinson's who had a particular problem with moving too slowly, while they were having surgery under a local anaesthetic to replace the battery of their existing DBS implant. Brown's team found that the responsive stimulation caused less speech impairment than conventional constant stimulation, and it was about as effective at combating slow movements (bioRxiv, doi.org/dp5f).

However, the approach might not be suitable for everyone. Responsive stimulation led to the recurrence of the tremor in two patients. Tremor may be caused by problems in different nerve clusters, says Brown.

Tim Denison at the University of Oxford, who wasn't involved in the study, is trying to develop another kind of responsive DBS that targets the approach's other main side effect: involuntary jerky movements. By introducing a second wire on the surface of the brain, his team has found that these movements are accompanied by another kind of brain wave, known as gamma waves, in an area called the motor cortex.

He hopes that people could have their DBS activity turned down automatically when gamma waves are detected. "This is where the field is heading," says Denison. ▮

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Diet

Sugar or sweetener? Your gut can tell the difference

Jessica Hamzelou

CAN you taste the difference between sugar and a zero-calorie sweetener? It seems specialised cells in your gut probably can within milliseconds.

Research in the 1950s revealed that food doesn't need to pass through the mouth to stimulate the brain – mice respond in this way when foods are put directly into their stomachs, too.

Two years ago, Diego Bohorquez at Duke University in North Carolina and his colleagues identified a new type of cell that gives the gut its own ability to sense nutrients. These neuropod cells were spotted in the intestines of mice, and rapidly sent signals via the vagus nerve, which links the gut to the brain, related to the presence of sugary snacks.

To find out whether these cells can tell the difference between sugar and zero-calorie sweeteners, the researchers put a range of sugars and sweeteners into the guts of mice. At the same time, the team used a device to measure vagus nerve activity. All of the sugars triggered the neuropod cells to send a signal to the vagus nerve – except for fructose.

The fact that fructose, a natural sugar found in fruit, doesn't seem to trigger a rapid signal to the brain may explain why fruit doesn't give our brains the same reward as chocolate, says Elisa Hill at RMIT University in Australia. "It would be great to know if these systems can be trained to favour fruit over chocolate," she says.

In another set of experiments, Bohorquez and his team studied organoids, small lumps of living tissue grown from cells taken from the intestines of mice or humans. The team found that only sugars that contained calories triggered release of a compound called glutamate as a signal to the vagus nerve. Zero-calorie sweeteners delivered an entirely separate signal to the vagus nerve, via a compound called ATP (bioRxiv, doi.org/dp43).

"It would be great to know if sweet-sensing gut cells can be trained to favour fruit over chocolate"

The findings suggest the gut senses the sweet taste and calorie content of substances separately, and sends both signals to the brain within milliseconds. This sense might have evolved to enable animals to find energy-rich foods, says Jonathan Swann at Imperial College London. "Determining what's energy-dense and what's energy-scarce would be very important in seeking out foods."

It is likely that similar cells are doing the same thing in people's guts, says Hill. If so, tinkering with the way the cells work may influence the way our brains respond to sweet foods. In the future, the cells could be targeted in treatments to modify eating behaviours and for some people with obesity, she says.

Neuropod cells may also be a way for gut bacteria to rapidly communicate with the brain, says Swann. Disruptions to the gut microbiome have been linked to a range of neurological disorders, including Parkinson's disease and mood disorders. ▮

Even without tasting them, our bodies may tell sugars from sweeteners

ANTONIO GUILLEM/GETTY IMAGES

Animal behaviour

Penguins call out under water but we don't know why

WE KNOW that whales, dolphins, seals and even sea turtles vocalise under water – and now we have discovered that penguins do it too. It is the first time seabirds have been found to produce such sound beneath the waves.

"The use of acoustic signals at sea could potentially enhance seabirds' foraging success, but this remains largely unexplored," says Andréa Thiebault at Nelson Mandela University in South Africa.

She and her team fixed cameras and audio recorders to a variety of penguins – six king, 10 gentoo and two macaroni – at Marion Island, South Africa. The kit was designed for pressures up to 300 metres down, where the animals hunt.

They recorded a total of 203 vocalisations during nearly 5 hours of underwater footage.

Beneath the ocean surface, penguins make short chirps as they chase prey

PAUL SOUDERS/GETTY IMAGES

The sounds were very short chirps – 0.06 seconds on average – and differed from the penguins' land vocalisations, which are around 3 seconds long, much louder and include a variety of sounds (*PeerJ*, doi.org/dp49).

Prior to the study, the team had been studying how Cape gannets and African penguins interact with their own species on the surface of the sea during foraging trips.

"With African penguins, we found their calling increased in frequency when they went out feeding on their own. This told us that they call to aggregate or attract other penguins… as their foraging success is greater when they forage in groups," says Pierre Pistorius at Nelson Mandela University.

While they are still figuring out what the penguins are saying under water, most of the vocalisations took place just before capturing prey. Pistorius says the calls could mean anything from "Hooray, food" to "Help me catch it". The sounds might even be used to disorientate prey. ▮

Nicky Willemse

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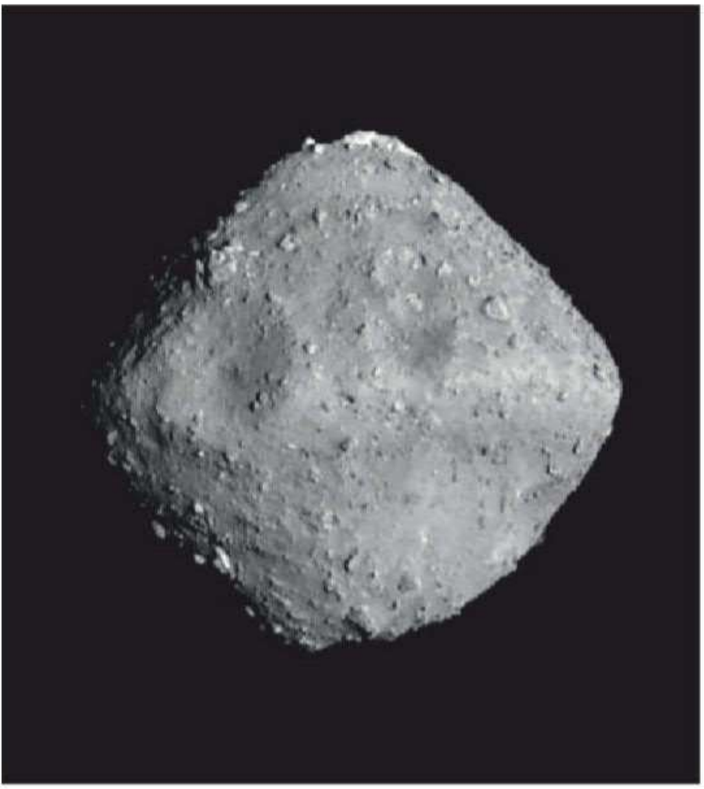

JAXA

Solar system

Space rock Ryugu gives up secrets of its age

BOMBING an asteroid has taught us how old it is. In April, the Japanese Hayabusa 2 spacecraft launched a copper projectile at the asteroid Ryugu, and now we have the first data on the crater it left behind.

The main purpose of this was to collect a pristine sample of the material beneath the asteroid's surface. But Masahiko Arakawa at Kobe University in Japan and his team analysed images of the collision to study the crater formation process.

When the 2-kilogram projectile smashed into Ryugu, it blasted away sand and rocks and moved a 5-metre-wide boulder. The resulting crater was about 14.5 metres wide and 2.3 metres deep.

We can use the number and size of craters on asteroids to estimate how old they are. Previous studies of Ryugu (pictured) determined that it was either about 9 million years old or about 160 million years old, depending on how much the size of craters there has been limited by the strength of the asteroid's surface.

From observing the formation of this new crater, the researchers found that underneath its blanket of boulders, Ryugu's surface isn't very sturdy. It is more like sand than rock. They say this confirms that Ryugu is only about 9 million years old (*Science*, doi.org/dp6q).

Asteroids like Ryugu form when larger objects get smashed up and the remnants reaccumulate into "rubble piles". There is usually lots of debris left behind from such a smash-up, and we may be able to identify other objects in the asteroid belt that are related to Ryugu in the future. **Leah Crane**

Biomaterials

Fishy solution to making flex screens

THE scales of fish could provide an eco-friendly alternative to plastic for use in flexible displays for electronic devices.

Flexibility is important for wearable electronics that need displays that bend, fold or twist easily, says Hai-Dong Yu at Nanjing Tech University in China. Plastic has been the go-to material for this, but sustainable, low-cost alternatives are sought after.

Fish scales account for 3 per cent of the 70.5 million metric tonnes of fish processed globally each year. The scales usually go to waste, but Yu and his team saw potential for flexible electronics.

They extracted gelatin from scales and used this to create an extremely thin film of material. Tiny silver nanowires were incorporated into it, to act as electrodes, along with a light-emitting material to provide light for the electronic display.

The result was a flexible display that fully biodegraded after 24 days in soil. A plastic display can takes centuries to break down. "We are excited about boosting the development of green, flexible electronics, which may drive a paradigm shift in our daily life," says Yu.

He says that, in addition to biodegradability, the fish-scale films have the advantages of high transparency, low surface roughness and low cost. They can also be easily recycled by dissolving them in warm water (*ACS Nano*, doi.org/dp6m).

Dipankar Mandal at the Institute of Nano Science and Technology in Mohali, India, says we can expect to see more "bio-electronics" like this in the near future. Alongside fish scales, other biological materials are being explored for similar purposes, including cellulose from cotton fibres and silk protein from silkworms. **Layal Liverpool**

Pollution

Just opening a bottle releases microplastics

TINY pieces of plastic pollution are produced just by opening a bottle or tearing a food wrapper.

Microplastics are between 0.001 and 5 millimetres in size and are usually either produced directly, or form when large plastic debris breaks up. We know that millions of tonnes of microplastics get into the environment and can harm marine life. Microplastics are also found in food, although the effect on human health is still unclear.

KANA DESIGN/GETTY IMAGES

Cheng Fang at the University of Newcastle, Australia, and his team tested whether everyday activities could be part of the problem. They opened common plastic items such as bags, bottles and packaging film by twisting the bottle cap or tearing the bag, for example, or by cutting them with scissors or a knife.

The team used a scale that is sensitive to weights as low as 1 nanogram to collect and measure the microplastics that landed on its surface. Between about 10 and 30 nanograms of microplastic were released from opening the plastic items – between 14,000 and 75,000 individual particles. But the team says that the true amount released is probably even higher, because many of these particles are statically charged and remain in the air.

Most of the fragments were made of polythene, a widely used plastic (*Nature Scientific Reports*, doi.org/dp6z). **Gege Li**

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Really brief

MIHAJLO MARICIC/EYEEM/GETTY IMAGES

An electric ride really is better

Electric cars now have a smaller climate change impact than their fossil fuel counterparts in almost every part of the world, according to researchers who say the vehicles are the best environmental choice even where power grids haven't gone fully renewable (*Nature Sustainability*, DOI: 10.1038/s41893-020-0488-7).

Interstellar visitor may be cracking up

The interstellar comet 2I/Borisov is starting to brighten, suggesting it may be breaking apart as it makes its way out of our solar system. Outbursts from the comet in early March have more than doubled its brightness, suggesting it is emitting material after being heated by the sun.

Random walks take maths prize

Mathematicians Hillel Furstenberg and Gregory Margulis have jointly won the 2020 Abel prize, worth 7.5 million Norwegian kroner (£540,000). They both invented techniques that use a "random walk" approach to study various mathematical objects.

Genetic modification

Brain cells turned into cyborg tissue

NERVE cells in living animals have been genetically modified to produce conducting polymers on their surfaces, giving them new electrical properties.

The work, which could enable us to electrically control specific groups of cells, may lead to new treatments for epilepsy and better ways of connecting prosthetic limbs to nerves, says Zhenan Bao at Stanford University in California.

At present, electrical implants, such as those used for treating Parkinson's disease, often use metal electrodes pushed into the brain. One of the disadvantages is that there is no way to use these to control the activity of particular types of neuron.

Bao and her team genetically modified specific cell types to make an enzyme on their surface that joins small molecules, known as monomers, to make a chain. The resulting polymer can be an electrical conductor or insulator, depending on the molecules used.

The team did this first with animal and human cells in a dish, then with miniature human brain-like structures in the lab and finally in living nematode worms, which were soaked in monomers.

The researchers showed that targeted nerve cells become coated in a polymer of choice, and that this alters the behaviour of the cells as expected. For instance, targeting the neurons that control movement in nematode worms made them less likely to move forward, or more likely to make sharp turns, depending on the type of polymer (*Science*, doi.org/dp64). **Michael Le Page**

Marine biology

NOPADOL UENGBUNCHOO/GETTY IMAGES

Fish parasite numbers have soared in recent decades

FISH are burdened with lots more parasitic worms than 40 years ago.

***Anisakis* worms infect marine fish, squid and marine mammals, and can be in fish used for sushi. Chelsea Wood at the University of Washington in Seattle and her team analysed changes in abundance between 1978 and 2015, looking at the average number of these parasites per fish from 123 studies spanning 215 species. They found a 283-fold increase over that time (*Global Change Biology*, doi.org/dp6r).**

These worms start life in the intestines of marine mammals, which excrete them. They can then infect fish, small crustaceans or krill.

Humans can ingest these worms by eating infected fish that is raw, smoked or improperly frozen. They can't survive in us, yet can cause vomiting and diarrhoea. But Wood says we needn't be overly worried, as the seafood processing industry and sushi chefs are skilled at spotting and removing the worms.

The reason for the increased abundance of the parasites isn't clear, but Wood says that it may be linked to a rise in marine mammal numbers from the 1970s onwards. Warming seas may also increase *Anisakis* reproduction, she says. **Donna Lu**

Medical technology

Ultrasound can check our brains

ULTRASOUND head scans could be used to quickly diagnose strokes.

Ultrasound produces pictures of a body's insides by transmitting and recording the echoes of sound waves. It is most commonly used to monitor fetuses during pregnancy. Now, Lluís Guasch at Imperial College London and his colleagues have developed a version that produces images of our brains.

Until now, ultrasound wasn't used to scan the brain because the resulting picture was distorted by the skull. But the new technique overcomes this by pairing the recordings with an algorithm that takes account of any interference produced by the skull (*npj Digital Medicine*, doi.org/dp6x).

This method could be easily employed outside the hospital setting as the equipment is relatively small and inexpensive.

This could be useful for treating stroke. People who have a stroke must be diagnosed quickly so the right treatment can be given to avoid further damage.

Typically, this is only possible with brain imaging, using MRI or CT scans. Both of these can only be done in hospital, which usually means a delay.
Jason Arunn Murugesu

Coronavirus in the US

Weakened defences

The way society functions in the US has made it more vulnerable to pandemics. Could things be different, asks **Chelsea Whyte**

THE coronavirus outbreak is a once-in-a-century event – and it seems the US has spent the past 100 years unwittingly weakening its defences.

In fact, the US is probably the developed economy with the worst type of healthcare system to tackle covid-19. Many economic and healthcare policies it has enacted don't prioritise public health, and it is finding out first-hand how dangerous that can be.

The impact of this has been seen in the past month or so in the lack of testing – as of 23 March, the US has done 238,632 tests compared with 338,036 in South Korea, a far smaller country.

"We don't have enough resources to do the testing quickly enough, and have been slow to measure the epidemic and reduce its spread," says Ben Sommers, a health economist and physician at Harvard University.

But the long-term issue is that many people in the US simply don't have adequate healthcare, he says. "The biggest holes in our system are the issues of affordability and financing."

About 8 per cent of people in the country don't have health insurance – and many more have plans that don't cover the full cost of healthcare. In early March, a man in Florida said that even though he had insurance, he was expected to pay about $1400 to get a test for covid-19. As businesses close to enable social distancing, some people will lose their jobs and with it their employer-provided insurance.

The US Centers for Disease Control and Prevention has now lifted restrictions on testing and made it free to all. But Sommers points out that if someone needs care for severe symptoms – for example, a ventilator in an intensive care unit (ICU) to help them breathe – that care won't be covered by the federal government.

JOSH EDELSON/AFP VIA GETTY IMAGES

People who are homeless are some of the most vulnerable to covid-19

That isn't to say that universal healthcare coverage is a panacea. The US has one of the highest number of ICU beds per 100,000 population, at 34.7 according to the latest figures available. The UK, with its National Health Service, has just 6.6, while Italy, with a similar universal service, has 12.5. "I understand the temptation to look at the new coronavirus and say we need to get everyone covered. As we see in Italy, that alone isn't going to fix this," says Sommers.

$1400

Amount one man was asked to pay for a covid-19 test in the US

While universal healthcare can't stop the virus spreading, as seen in Italy, it may make it easier to respond to the wider economic crisis. Sommers says it is one of many healthcare policies that builds infrastructure and creates patient-doctor relationships that can help people stay healthy and working.

The US now seems to realise this. Emergency spending bills have already included money for expanding access to Medicaid, a US government programme to help people with low incomes pay medical costs. "If we spend 100 billion more dollars on direct medical care, trade that off with the losses from a significant recession if we don't. This is one case where it makes sense not to be stingy," says Sommers.

Healthcare isn't the only worthwhile investment. Many countries have widespread paid sick leave, and it is now becoming clear that this is a public health shield, not an employment perk. Japan, Canada and the US are three major economies that don't have paid sick leave, while provision in some places, including the UK, has been undermined by the rise of the gig economy. Self-employed people don't normally get sick pay in the UK, but the government has said this will change.

"Precisely because we need people to stay home when they're sick, there is a case to be made for unlimited provision of paid leave for those who do not have it," says Veronique de Rugy, an economist at the Mercatus Center at George Mason University in Virginia. But again, this isn't a simple solution.

"If you have no customers coming into your stores and on top of that you have to provide extra payment to your employees in the form of sick leave, it could be a problem. It could create an incentive to get rid of employees," she says.

This might not normally be an issue, as Catherine Maclean at Temple University in Pennsylvania and her colleagues found when they examined five US states that adopted paid sick leave between 2009 and 2017. "For those employers induced to provide the coverage, employees take about two more days of paid sick leave per year. The cost per employee hour is about 21 cents," says Maclean.

With a 14-day quarantine suggested by public health officials, however, the cost in the current outbreak is likely to be much higher. But Maclean says this policy, along with better health insurance and stronger food

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voucher programmes, could help to limit the effects of the pandemic.

The most vulnerable people are facing even tougher times ahead. People who are homeless are at higher risk, for example. “When you think about what we need to do in a crisis like this – keep away from others, wash your hands all the time, don’t share utensils, keep a store of medicines, or shelter in place – those things become impossible when you’re homeless,” says Margot Kushel at the University of California, San Francisco.

Many homeless people have chronic medical conditions and are more likely to rely heavily on hospitals. About half of homeless adults who are single are over 50, says Kushel. Older people who contract covid-19 are more likely to have severe symptoms and die.

“Cities and counties are scrambling to figure out where people who are homeless who have mild diseases can go. We’re going to need every hospital bed we can get,” she says. An analysis of Italy’s hospital bed capacity suggested that the country’s ICUs would be overwhelmed by people with covid-19, a prediction that has come true. In some regions, a majority of those beds are being used by people with covid-19 who need to use ventilators, it found. That doesn’t leave enough room for people who need emergency medical care due to other diseases.

An analysis of the situation in the US by the Harvard Global Health Institute suggests that even in a best-case scenario where covid-19 cases take place across 18 months, ICU beds in the US would be 95 per cent filled. But we have seen the disease spread faster than that in other countries. In a worse-case scenario, where 60 per cent of people in the US contract the disease in six months, the country would need seven times the number of hospital beds it has.

> **“There is a case to be made for unlimited provision of paid sick leave for those who do not have it”**

Countries could have designed a system with more slack, building more hospitals than they would normally need rather than trying to always operate as efficiently as possible. This is an argument that pops up yearly in the UK during the normal winter flu season, when hospitals reach breaking point. Once again, there are no easy answers.

“To triple our ICU capacity when it won’t be used in the long-term is not the answer. You can’t just sit around on those resources. They’re tremendously expensive. We have to figure out a way to be flexible,” says Sommers. Some countries have begun building temporary hospitals or using hotels for people with covid-19.

Some of the changes this pandemic brings about may alter healthcare for good. Many doctors are setting up the ability to offer medical advice and diagnoses over the phone. “Putting that telehealth infrastructure in place will let that continue after the epidemic subsides,” says Sommers, which could help improve access to healthcare.

The same thing goes for the economy, says de Rugy. “Overpreparedness has a really big cost and it doesn’t make sense if the emergency we have is one that occurs every 100 years,” she says. “Maybe the best investment is developing a process to more quickly assess the emergency at hand and then act.”

In the US, such a process could be informed by the president’s advisers on the National Security Council. After the Ebola outbreak in West Africa in 2014 to 2016, President Barack Obama set up a permanent working group to advise on matters of global health security and help coordinate a response to future pandemics like the current one. The Trump administration disbanded the group in 2018. ▮

Money for all?

To limit the economic damage of the coronavirus pandemic and help people continue to take care of their basic needs, some have proposed countries introduce a universal basic income (UBI), paid by a country’s government. This would help people who have lost jobs or customers for their business, as well as those facing unexpected medical costs.

While not quite universal, the UK government last week announced it would encourage employers to keep on staff unable to work by funding 80 per cent of their salaries, up to a maximum of £2500 a month.

Some people, including former UK cabinet member Iain Duncan Smith, have said that a UBI could discourage people from seeking work. But a two-year experiment in Finland suggested that a UBI doesn’t significantly alter the number of days someone will work in a year. Similar findings came from a study in the state of Alaska, where residents receive a yearly payment of between $1000 and $2000, funded in part by oil revenues.

Working hypothesis

Sorting the week’s supernovae from the absolute zeros

▲ Black rhinos

Who has a big horn and is dodging extinction for now? This guy! African black rhino numbers are up to 5630 in 2018, from 4845 in 2012.

▲ NASA insight

NASA’s InSight spacecraft has been trying to push a probe into the Martian soil, and finally succeeded by hitting it with a shovel.

▲ Lost continent

Diamond samples found near Greenland have revealed that an ancient part of Earth’s continental crust is 10 per cent larger than previously thought.

▼ Mini-moon

Lil’ moon, we hardly knew ye. A tiny space rock discovered in Earth orbit last month has now flown on its merry way.

▼ Netflix

The streaming giant is cutting video quality in Europe to reduce data use by people self-isolating. If this goes on much longer, we might have to actually talk to each other.

LIFES ALL WHITE/ALAMY

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Views

The columnist
Chanda Prescod-Weinstein on the Hubble constant **p24**

Letters
The effects of pandemic across the social gradient **p26**

Aperture
Meet the sea creature named in the fight against plastic **p28**

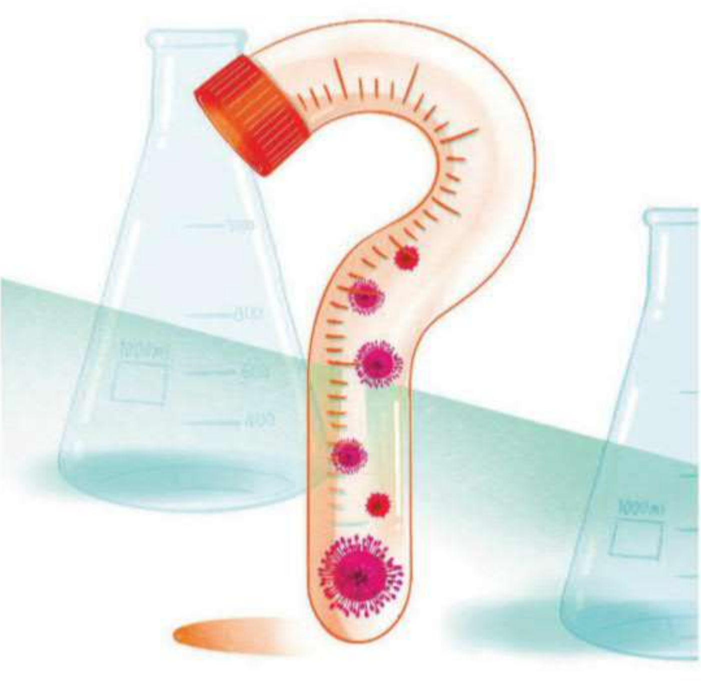
Culture
Solving the mystery of life’s giant leaps of evolution **p30**

Culture columnist
Jacob Aron on why he loves blasting *Doom* demons **p32**

Comment

Beyond the science of covid-19

Models of the new coronavirus’s spread are imperfect, so factors other than the science play an important role too, says **David Adam**



JOSIE FORD

“TAKE nobody’s word for it.” That is how the motto of the UK’s Royal Society, *Nullius in verba*, is usually interpreted. It is a warning against listening to arguments made purely from authority. Only the science – data and evidence – is persuasive. But what about when the science itself is presented as the de facto authority?

As the covid-19 pandemic tightens its grip, politicians in the UK and elsewhere have been invoking “the science” as their spirit guide, especially as a defence when their policies and actions (or lack of them) are criticised.

Decisions on covid-19 have to be made urgently, and it is correct to take the latest scientific expertise into account. Evidence-based policy-making is presented as the gold standard and rightly so, especially in public health. But it is vital to stress that “the science” of this pandemic – and what should be done in response – is quite different from “the science”, say, of how soap and water protect against the coronavirus.

The benefits of the latter in handwashing are based on established facts, testable ideas and the results of properly planned experiments. It is knowledge; science used as a noun. Whereas research on covid-19, and in particular the policy response, is science as a verb. It is uncertain, transitive, contested and volatile. No scientist would argue otherwise, of course, and those involved in coordinating the policy response have been at pains to point out the limitations and uncertainties in their thinking, and the preliminary nature of the findings.

But politicians don’t like to stress uncertainty. UK prime minister Boris Johnson repeatedly says his government’s actions are based on “the best science”. Campaigners on Twitter and elsewhere who wanted the UK to close schools earlier than it did had urged the government to listen to “the science”.

Those in the UK can see much of that science for themselves. Researchers at Imperial College London who are advising the government have published a summary of the results of their modelling, including the assumptions it rests on.

The importance of these assumptions is underlined by what happened when the team got hold of some updated data on what proportion of people hospitalised by covid-19 would need intensive care. The initial estimate was 15 per cent. But when the researchers doubled that to 30 per cent, based on reports from Italy and China, the model said that 250,000 people would die.

That single change seems to have been enough to trigger severe new restrictions on public gatherings and social contact.

But those policies are based on assumptions of their own: that half of households will comply with requests to self-isolate for 14 days if someone shows symptoms, for example. And that closing schools and three-quarters of universities will actually increase community contact between infected and uninfected people by 25 per cent. How reliable are those numbers? We just don’t know.

Earlier this month, an editorial in *The Guardian* complained that the UK’s response to the virus was “confused and hesitant”, and argued that disclosure of the scientific evidence was needed to protect public trust. Yet confused and hesitant is how the best science proceeds.

Policies, even evidence-based ones, aren’t based on science alone. They emerge from a process that also accounts for values and priorities. Right now, politicians must balance the way a wider lockdown of the population could help reduce infection, against the negative sociological consequences of isolation and the impact on civil liberties. These are political decisions, and they must be seen and presented as such, particularly as the continuing pandemic and the severe restrictions on people’s lives start to fray the collective patience. ▮

David Adam is a consultant for *New Scientist*

Field notes from space-time

Hubble in crisis

The universe is expanding, but sums at the heart of the process don't seem to add up. What we learn next may alter our view of the cosmos, writes **Chanda Prescod-Weinstein**

Chanda Prescod-Weinstein is an assistant professor of physics and astronomy, and a core faculty member in women's studies at the University of New Hampshire. Her research in theoretical physics focuses on cosmology, neutron stars and particles beyond the standard model

Chanda's week

What I'm reading

I am excited to dig into fellow scientist Brandon Taylor's debut novel Real Life.

What I'm watching

I am really happy that NeNe and Porsha made up on The Real Housewives of Atlanta.

What I'm working on

Working during a pandemic is hard, but I am starting some new work involving machine learning, and that is fun.

This column appears monthly. Up next week: Graham Lawton

IT IS nearly 100 years since we confirmed that the universe – space-time – is expanding. But we are still struggling with a basic fact: what is the rate of the expansion? Depending on how we measure a crucial number that sets this value, we seem to get different answers. The fallout of this question could drastically change our understanding of the cosmos.

In 1929, astronomer Edwin Hubble used observations of galaxies to show that there was a correlation between their velocity and their distance from us. The further away they were, the faster they seemed to be receding from our galaxy. General relativity, which at that point had only been around for a decade and a half, had a clear theoretical explanation for this finding: space-time isn't static. It expands, carrying galaxies along like a raft on a river.

Hubble was able to make this radical discovery because of something we now call Leavitt's law. Discovered by Henrietta Leavitt in 1908, the law concerns young stars called Cepheid variables. These stars are called variable because their brightness and size vary.

While working as a computer at Harvard College Observatory, Leavitt noticed that Cepheids had a pattern: the power of their light emission – absolute magnitude, to astronomers – correlates with the frequency of the pulsations. In other words, by observing these, one could calculate their absolute magnitude, which we could then use to calculate how far we are from an object.

Leavitt's law created a rung on what we call the cosmological distance ladder, which is a collection of different ways that we measure distances to objects in the sky. Cepheids proved to be a powerful tool because they are found in other galaxies. Hubble took advantage of that, leading to his finding that galaxies move away from us at a velocity directly proportional to their distance from us. The proportionality constant of this relationship is known as the Hubble constant.

Ninety years after Leavitt discovered her law, astronomers were making distance measurements using exploding stars known as type Ia supernovae. They found something unexpected: not only is space-time expanding, but that expansion is accelerating, like a river current picking up speed. The discovery of cosmic acceleration, as this phenomenon is known, netted three of the astronomers involved a Nobel prize.

> "The discovery of cosmic acceleration netted three of the astronomers involved a Nobel prize"

For a time, discussions of expansion focused primarily on the problem of explaining cosmic acceleration. But now astronomers are spending a lot of time arguing over the exact value of Hubble's constant.

Adam Riess, one of the cosmic acceleration Nobel laureates, has been leading a team that used type Ia supernova to find a value for the Hubble constant that is 12 per cent larger than one produced by a different method involving the cosmic microwave background (CMB) radiation, the leftover radiation from the big bang. This difference is much larger than the margin of error involved, which means that the two measurements appear to be in disagreement, assuming they are taking all of the right physics into account correctly.

As wonderful as Cepheids are, because they are young stars, they tend to be surrounded by dust. This is a problem because it can obscure measurements, making them inaccurate. It means there may be errors in Cepheid-based calibrations of type Ia supernova distances, leading to an error in the distances calculated from observations of them.

In fact, the Panchromatic Hubble Andromeda Treasury collaboration (PHAT) has since found that Riess and his team may have the wrong calibrations for their Cepheids and this may be partly due to their use of ground-based telescopes as opposed to something in space like PHAT uses. The callibrations also suffer from crowding – the possibility that what looks like one star is actually several – and this effect can get worse with distance.

In July 2019, astronomer Wendy Freedman said these inconsistencies are "what keeps [her] up at night". She is leading a team that is using another type of star to measure the Hubble constant: those in the so-called tip of the red giant branch, known as TRGBs. These stars are maybe half the mass of the sun, and are at a later stage of their lives where helium burning has begun in their cores, after all of their hydrogen has burned up. Earlier this year, Freedman's team published a paper saying that calibrating type Ia supernovae with TRGBs leads to a Hubble value that is somewhere between that suggested by CMB measurements and what Riess's team has found.

Why are these values so different? We just don't know – and not knowing is part of what makes science so fun. ▮

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Editor's pick

The effects of pandemic across the social gradient

14 March, p 9

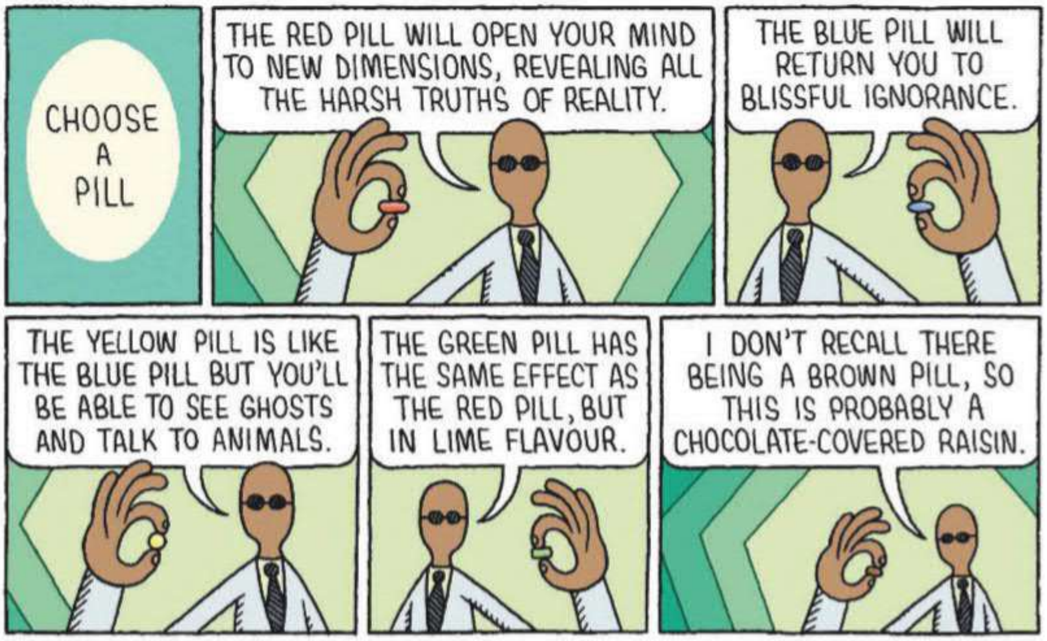
From Margaret Brown, Burslem, Staffordshire, UK

Jessica Hamzelou reports that the risk of dying from covid-19 rises with age, diabetes and heart disease, with around half of deaths from the infection involving people with underlying diseases.

But when it comes to age, calendar age isn't the only way to look at this. People age, biologically speaking, at different rates. Those lower down the socioeconomic scale may be more vulnerable to ageing faster in this sense.

Differences in life expectancies have already been increasing across this "social gradient". The average age of death of homeless people is 47. Deprivation ages people and lessens resistance to illness.

On a large scale such differentials could have significant demographic, and therefore political, effects. Is anyone working out what these effects could be for the coronavirus?


CHOOSE A PILL
THE RED PILL WILL OPEN YOUR MIND TO NEW DIMENSIONS, REVEALING ALL THE HARSH TRUTHS OF REALITY.
THE BLUE PILL WILL RETURN YOU TO BLISSFUL IGNORANCE.
THE YELLOW PILL IS LIKE THE BLUE PILL BUT YOU'LL BE ABLE TO SEE GHOSTS AND TALK TO ANIMALS.
THE GREEN PILL HAS THE SAME EFFECT AS THE RED PILL, BUT IN LIME FLAVOUR.
I DON'T RECALL THERE BEING A BROWN PILL, SO THIS IS PROBABLY A CHOCOLATE-COVERED RAISIN.

TOM GAULD for NEW SCIENTIST

There are many shades of autism

7 March, p 56

From Tom Clements, Bishop's Stortford, Hertfordshire, UK

It is a noble thing to celebrate the emergence of young autistic activists like Siena Castellon who embrace autism as an intrinsic part of their identity. But for many on the autism spectrum, it simply cannot reasonably be considered to be a bright thread in the rich tapestry of neurodiversity.

While Castellon's success as a self-advocate is laudable, there remains a significant subset of people with autism who rely entirely on the care of others for their entire lives. Many will self-injure and will have to wear protective helmets. Others will experience difficulty bathing or completing simple tasks such as buttering bread or tying shoelaces. Far from conferring any cognitive advantages, their autism hinders them so severely that they live in a permanent state of dysfunction.

This reality runs contrary to the trend to celebrate neurodiversity, and is therefore increasingly glossed over in contemporary autism discourse. A result is that the most severely affected autistic people, many of whom can't speak and so have no voice in advocacy, are being marginalised as a result of a focus on those with above-average intellectual gifts.

For the sake of fairness, the other side of autism must be highlighted as a counterbalance to those narratives that only accentuate the positives of this complex and varied condition. Otherwise, the cognitive divide in the autism community will only continue to widen.

From Jonathan Mitchell, Los Angeles, California, US

I am a 64-year-old man with an autism spectrum disorder. This has impaired my ability to make a living, prevented me from ever having a girlfriend, and has given me problems with fine motor coordination, phobias and a voice volume I can't control. It has made my life hell. As the neurodiversity movement gains greater traction, people may be less encouraged to find solutions for the many for whom this is a grave problem.

Thoughts on surviving being lost in the wild

29 February, p 40

From Debby Potts, London, UK

Michael Bond's report on the behaviour patterns of people who find themselves lost in the wild shows how many will panic and make unsafe decisions. But that may not tell us everything about how all people react.

Most of those who get lost are never reported missing for the simple reason that they manage to find their way back before that happens. Many may have sensibly retraced their steps. Others may have carried on for hours – against the standard advice – until they found a landmark or path that helped them reorient themselves.

The lesson from social science studies is that, to understand the outcomes of all people's choices, it is vital to include in your sample not only those for whom a situation went wrong, but also those who managed to rectify it.

From John Leonard, Canberra, Australia

Bond notes that people lost in non-urban spaces tend to keep on the move, making it more difficult to find them. I suggest that the reason for this goes beyond fear. It is difficult to keep warm without a fire – or very good camping gear – in any cooler climate, at night, or when it is wet. Staying on the move keeps you warm.

From Georgina Skipper, Weymouth, Dorset, UK

I have to take issue with Bond's statement that "millions of years of evolution have taught us that the experience [of being lost] tends not to end well". It may be possible that epigenetics are affected by experiences of this sort, but evolution takes place through creatures that survive and reproduce, not those for whom the experience hasn't ended well.

That said, I think there is a link between a fear of being lost and a fear of being hunted, possibly inherited from ancient ancestors.

Promising to plant trees isn't enough for climate

29 February, p 20

From John Foot,
Wokingham, Berkshire, UK

I read Adam Vaughan's discussion of several initiatives to plant or protect a trillion trees around the world with interest. But, like all the pieces I've read on the subject, it seems to address only part of what is required to make this effective.

Surely there should be a strategy to lock away the carbon from mature and felled wood. Burning it or letting it rot away just returns the carbon to the atmosphere.

Nature offers several solutions for this, including preserving wood in peat bogs or lakes. On very long timescales, this can lead to the formation of oil and coal.

From James Runacres,
Kirby Muxloe, Leicestershire, UK

I am curious to know what percentage of the promised newly planted trees will survive to an age at which they can be considered to be "established".

For example, in the 2019 UK general election, parties proposed tree planting to counter domestic carbon emissions. But if many new trees don't get established, then the net effect would be a lot less than advertised. Are there any studies that provide estimates for tree planting success rates?

Semi-autonomous cars are the worst of both worlds

Letters, 8 February

From Toby Pereira,
Rayne, Essex, UK

Anna Zee says motion sickness would be an issue for people deprived of a sense of control in autonomous cars.

The problem she raises of a driver potentially having to take over a semi-autonomous vehicle when afflicted in this way is just another good reason why semi-autonomous vehicles are less safe than those that are manually driven or those that are fully autonomous.

If we live in a simulation, we can't debug its code

Letters, 22 February

Ed Subitzky,
New York, US

Reading the recent letters about whether or not we live in a computer simulation led me to think about the matter of software bugs if this were true.

Every piece of software of any complexity contains them, and presumably the software engineers who coded the simulation in which we may live also left a few (or perhaps more than a few) in their creation. But what is or isn't a bug can depend upon one's point of view.

To the software engineers, a bug is computer code that produces an unintended result. But, being inside the simulation, we couldn't recognise such a bug because, to us, it would simply be a part of the basic structure of our universe. It would be a brute fact or "law of nature". Or perhaps we could recognise it as an anomaly that doesn't make sense in terms of the rest of our universe (quantum physics, anyone?).

Perhaps I, or at least some of my traits, could be the result of a bug. Perhaps this letter to *New Scientist* could be the same.

From within the simulation, we naturally couldn't examine the code responsible for our existence, nor, most likely, be smart enough to understand it.

Part of the reason for that state of affairs is that, undoubtedly, the software engineers wouldn't want to make us as bright as they are, even if that were possible.

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50 years ago, *New Scientist* looked even further back to the dawn of universities

SIX hundred years ago, "the three pillars on which civilization rested were the Catholic Church, the Holy Roman Empire and the universities". This is how Bertram, Lord Bowden, principal of the University of Manchester Institute of Science and Technology in the UK, opened eight pages of coverage on "Universities and Society" on 26 March 1970.

He charted how universities came about, including a pivotal moment in 1415 when the rector of the University of Prague was burned alive, and "students fled in panic – to... Heidelberg and several other universities". The humanist, independent model they founded there was resisted in England. Bowden, developing the theme of independence, noted that 19th-century poet Matthew Arnold "discovered that Continental scholars refused to acknowledge that Oxford was a university... It was no more than an expensive finishing school for the scions of the aristocracy." Its image "haunts us in England even yet".

Into the 20th century many universities were loath to accept engineering and technology as subjects worthy of study, wrote Bowden. Again, he linked this to ideas of independence: "It is just as wrong for universities to allow themselves to be dominated by industry or by the government as it is for them to ignore the problems with which industry and government are struggling."

Clues to what prompted our coverage are in another part of it, in which Jonathan Rosenhead at the London School of Economics and student Tony Norden continue the independence theme, referring to "allegations that local industrialists... have been monitoring the external activities of certain left wing lecturers" at the University of Warwick, UK. The backdrop was a student occupation there earlier in 1970. Reports elsewhere said that the students felt the university administration "had become so... enmeshed with the upper reaches of consumer capitalist society that they are actively twisting the purposes and procedures of the university", and that the occupiers found files on surveillance of staff.

Our coverage concluded with the inauguration of the UK's Open University and its innovative distance learning. It would, Geoffrey Hollister and Michael Pentz predicted, be the perfect setting to develop "computer diagnosis, computer-aided design, and automatic traffic guidance". Those topics have filled our pages over the half century since.

Mike Holderness

To find more from the archives, visit newscientist.com/old-scientist

Deeply shocking

Photo BBDO/Weston/Jamieson

THE beautiful, interlocking, armoured plates of this amphipod are meant to keep it safe from predators and other threats. But they can't protect it from plastic pollution, which is how this creature got its name.

Eurythenes plasticus is a newly described shrimp-like species found between 6 and 7 kilometres down in the Pacific Ocean's Mariana trench, where Earth's deepest waters are found.

Johanna Weston at Newcastle University, UK, and her colleagues used baited traps to catch several specimens, which can grow up to 5 centimetres long. Analysing their hindguts revealed that one of them, a juvenile, had consumed a microplastic particle very similar to polyethylene terephthalate, or PET, a plastic often used to make water bottles and fabrics.

The team named the animals *plasticus* to send the message that even sea creatures living so deep are exposed to this pollution. And if a juvenile consumed plastic, this indicates that such scavengers could be "ingesting microplastics throughout their life, which could pose acute and chronic health effects", says the team (*Zootaxa*, doi.org/dp3m).

While the effects of exposure to microplastics haven't been studied in deep-sea amphipods, there is evidence that ingesting one form of these particles – polypropylene fibres – increases mortality in Pacific sand crabs. ▮

Chris Simms

Laying the bones bare

Finding out how flight evolved or how animals colonised the land is all about a collision of palaeontology and genetics, discovers **Graham Lawton**

Books

Some Assembly Required: Decoding four billion years of life, from ancient fossils to DNA
Neil Shubin
Oneworld

Fantastic Fossils: A guide to finding and identifying prehistoric life
Donald R. Prothero
Columbia University Press

PHIL DEGGINGER/ALAMY

Molecular biology is revealing deeper secrets of ancient life like *T. rex*

IN 1871, a now-obscure biologist called St George Jackson Mivart published *On the Genesis of Species*. As its title suggests, the book was a riposte to Darwin's theory of natural selection, published in 1859. Mivart had been an avid Darwinian, but the more he thought about it, the stronger his doubts grew. In particular, he couldn't see how natural selection could account for the appearance of novel structures.

This was the start of a debate that has raged ever since: just what caused the major transitions in the history of life? How, for example, did birds evolve flight? Or animals evolve to live on land? The problem is that a small, incremental step towards structures such as wings, feathers or lungs would appear to be of little adaptive value, and so wouldn't have been selected for by evolution. Ditto the sweeping anatomical and physiological changes required to take to the air or colonise the land. As the late palaeontologist and science writer Stephen Jay Gould put it, what use is 2 per cent of a wing?

Pretty much every major transition hits this problem, and creationists exploit it in their attempts to discredit the theory.

Neil Shubin at the University of Chicago is well placed to answer the question. As a palaeontologist, he predicted the location of, and then found, the fossilised remains of *Tiktaalik roseae*, a 375-million-year-old transitional form. *Tiktaalik* is what we used to call a missing link: it is an intermediate stage between aquatic and terrestrial animals, and one of the best pieces of physical evidence for the theory of evolution.

> “As palaeontologist and science writer Stephen Jay Gould put it, what use is 2 per cent of a wing?”

The story of *Tiktaalik*'s hard-won discovery in the Canadian Arctic was the centrepiece of Shubin's excellent previous book, *Your Inner Fish*. His latest book, *Some Assembly Required,* plays to his other specialism, molecular biology, where he works to understand how genetics and developmental biology explain such major transitions – for instance, how a class of regulatory genes called *Hox* orchestrate the development of all body plans.

His new book is a skilful and fascinating account of how his two very different worlds produce a coherent answer to the 2-per-cent-of-a-wing question. Spoiler alert: evolution rarely comes up with anything truly new but simply repurposes what is available. Thus lungs evolved from swim bladders, feathers from dinosaurs' insulating fuzz, and so on. When true novelty arises, it often comes from an unlikely source: viruses.

Shubin covers both the groundbreaking science and the scientists who broke it, telling a vivid and human story of the excitement, frustration and often sheer serendipity of progress.

Tiktaalik (and Shubin) also have a cameo appearance in another fine book by prolific author and palaeontologist Donald Prothero at California Polytechnic State University. Shubin and Prothero were university classmates and remain friends.

The buddies have produced very different books. *Fantastic Fossils* is an insider's guide to finding, collecting, identifying and understanding fossils, including a comprehensive walk through the different life forms that fossil hunters might hope to unearth, from sponges to vertebrates.

There is a lot of ground to cover, but enough "wow" moments to keep you going, much like a real-life fossil-hunting expedition. Did you know, for example, that the earliest turtles had shells on their bellies rather than their backs? Or that the 15-million-year-old leaves in the fossil beds of Idaho are so exquisitely preserved they are still green? There is all this and much more to enjoy in both of these books. ■

An ode to physics

Explaining the state of the art in physics is a job for one of the UK's most popular science communicators, says **Richard Webb**

Book

The World According to Physics
Jim Al-Khalili
Princeton University Press

ONE afternoon in 2016, *New Scientist* consultant Stuart Clark and I barricaded ourselves in a room, armed with flip charts and pens, in a bid to work out what fundamental physics looked like. This turned out to be a confusion of lines and arrows – dotted, looping, scribbled out, realigned – between boxes adorned with "$E = mc^2$", "uncertainty principle (?)", "quantum field theory" and "cosmic inflation!".

The finished product was more coherent. We were proud of it when it appeared in *New Scientist* – even if we had somehow forgotten about thermodynamics. We could have done with the clear mind of a Jim Al-Khalili. Loyalty doesn't allow me to admit he has made a better job of what we attempted, but his new book is really rather good.

Al-Khalili, a nuclear physicist at the University of Surrey, UK, is well known for BBC Radio 4's *The Life Scientific*, in which he interviews leading scientists.

He describes *The World According to Physics* as an "ode to physics", the subject he fell in love with as a teenager. Like Carlo Rovelli's bestseller *Seven Brief Lessons on Physics*, it is short. But in extending Rovelli's 96 pages to 300-odd, he offers a thorough overview of what physics says about reality and the problems created in so doing.

It is an interesting time for such a survey. The early 20th-century innovations of Einstein's relativity and quantum mechanics, and experimental and observational advances on scales from the very small to the vast expanse of the cosmos, more or less overturned everything we thought we knew.

These innovations allowed the development of two "standard models" – of particle physics and of cosmology – that, with the laws of thermodynamics, could be seen as telling us all we need to know. Yet as Al-Khalili observes, we are further away from the end of physics than we thought 30 years ago.

> "Al-Khalili's easy turn of phrase and feel for metaphor give a sense of physics as a box of delights and woes"

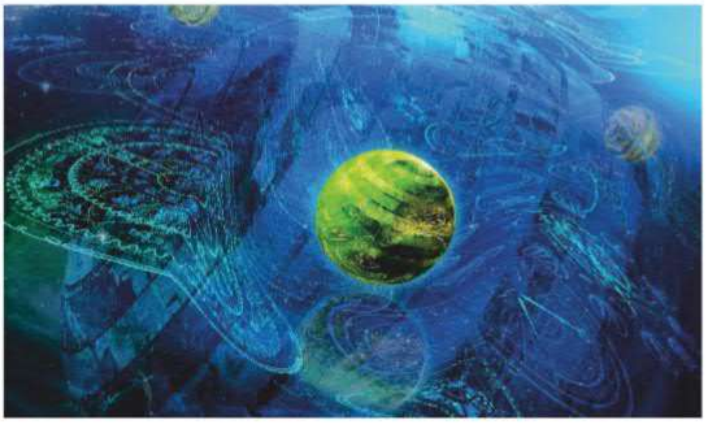
In part, that is because relativity and quantum mechanics provide us with very different, contradictory, pictures of such fundamentals as space and time. In Einstein's picture, these meld into one smooth fabric, space-time; in quantum theory, they remain strangely apart.

Once again, that is to ignore thermodynamics, which provides a third picture of the flowing time we experience, caused, as Al-Khalili tells it, by the increase of "useless energy", or entropy. Some argue this connection isn't so cut and dried. And to square our standard model of cosmology with observations of the universe, we had to invent dark matter and dark energy, which together make up 95 per cent of all stuff but which quantum theory (the directing theory of "stuff") can't explain. Lots still to do, then.

Al-Khalili's easy turn of phrase and feel for metaphor give us a sense of fundamental physics as a box of delights and woes. His true metier is quantum physics, where he is admirably lucid and even-handed in dealing with the various interpretations that seek to explain its picture of a "fuzzy" reality so at odds with our lived experience.

Here mystery builds on mystery, culminating in a split. Some say we shouldn't concern ourselves with the workings of the quantum world, because the picture the theory delivers squares with experiments and allows useful technologies to be built on top of it. Others believe physics should describe the world, and tell us why things are as they are. Al-Khalili is one such, but because he doesn't have a pet theory, he can argue both for fundamental physics and for the scientific method – less for offering enlightenment as a destination than for a thrilling journey.

Which, I think, was what our pens and flip charts were about too. ▮



HARALD RITSCH/SCIENCE PHOTO LIBRARY

Should physics describe the world and explain why things are as they are?

Don't miss

Play

The Complex features two scientists in a locked-down lab with time and air running out. This interactive bio-war thriller by Wales Interactive is released on PC, Mac, PS4, Xbox One and Nintendo Switch on 31 March.

Read

Greenery: Journeys in springtime (Jonathan Cape) by Tim Dee follows the arrival of spring in Europe, at walking pace, from the end of winter to the summer solstice, tracking the adventures of migrating birds. Bears, boars and bog bodies also star.

Listen

Futures is a podcast in which curator and host Luke Robert Mason interviews scientists, technologists, artists and philosophers as they try to imagine developments that might dramatically alter what it means to be human.

WALES INTERACTIVE; PENGIUN; LUKE ROBERT MASON

The games column

A welcome, adrenaline-inducing distraction

Doom Eternal involves killing demons, but the evidence suggests violence in video games has no real effect on behaviour in the real world, says **Jacob Aron**

Jacob Aron is *New Scientist*'s deputy news editor. He has been playing video games for 25 years, but still isn't very good at them. Follow him on Twitter @jjaron

Games

Doom Eternal

PC, PlayStation 4, Xbox One

Jacob also recommends...

Games

Superhot

PC, PlayStation 4, Xbox One, Nintendo Switch

An abstract sci-fi shooter with a unique twist – time only moves when you do. As a result, you can dodge bullets and line up seemingly impossible shots, before watching a real-time replay at the end of each level.

BETHESDA

Slaying *Doom*'s demons keeps the game moving forward

PLAYING *Doom Eternal* induces a physiological response in me – a fantastic adrenaline rush that is a welcome distraction in these dark times. The game is the second in a modern-day refresh of the long-running Doom series, which sees players blast away demons with an arsenal of absurd weaponry.

The immediate predecessor to *Eternal*, simply called *Doom*, came out in 2016, shortly before my first daughter was born. In her first few weeks, she refused to sleep in a crib and would only settle when lying on my wife or I. As a result, I became nocturnal, staying up most of the night with a tiny, precious bundle lying on my chest. In between swigs of coffee and episodes of *Line of Duty*, I turned to *Doom* to keep me awake.

What makes the 2016 game so engaging is a system designed to encourage forward momentum at all times: shoot a demon enough and it will flash orange, signalling you can move in for a "glory kill" that will send limbs flying and finish the job, restoring your on-screen health in the process.

The plot is irrelevant – demons have invaded Mars/Earth/whatever and only you can stop them... blah blah blah. All you need to know are two simple rules: keep moving and keep killing. *Eternal* expands on this with a flamethrower that makes enemies drop armour and adds a quick-dash move, meaning the whole game becomes a whirling ballet of balancing resources, such as health and ammo, and death-dealing. It requires extreme attentiveness and gets the heart racing satisfyingly.

> "The plot is irrelevant – demons have invaded Mars/Earth/whatever and only you can stop them... blah blah blah"

I realise that non-gamers reading this are probably horrified at my glorification of death and destruction, and some may already be reaching for their keyboard to complain. They wouldn't be the first – the *Doom* series has long been criticised for being too violent. However, looking back, it seems absurd to suggest the pixelated graphics of the 1993 original could ever warp young minds.

Video game violence isn't real-world violence, any more than chess is an accurate simulation of war, but many people feel the link is there. Concern over *Doom* probably reached its peak after the 1999 Columbine massacre in Colorado, in which two teenagers killed 12 students and a teacher at their school. Investigators found references to *Doom* in a journal belonging to one of the killers, and although there were rumours that he had recreated the layout of the school in the game, there is no evidence this is actually true.

So, do violent video games cause violent behaviour? Probably not. For a start, much of the research in this area relies on abstract measures of aggression – the length of time a participant exposes someone to a loud noise is often deployed, for example.

What's more, although a 2018 meta-analysis that looked at 24 studies, which together involved more than 17,000 people, found a slight association between video game violence and aggression in the real world, the effect size was tiny – accounting for less than 1 per cent of the variance in aggressive behaviour in US teens.

With little to show for years of study, researchers and the media seem to have switched to fretting about the negative effects of social media and smartphones. Again, the effects seem tiny if they exist at all – one paper found that eating potatoes has as much of an association with teen well-being as screen use. With that in mind, I'm happy to keep blasting demons. ■

New Scientist

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ASHLEY MACKENZIE

Reality in the making

Has quantum theory's greatest mystery been solved? **Philip Ball** investigates

IN THE minuscule realm of atoms and particles, it looks as though things exist not so much as things at all, but as vague clouds of possibilities. They seem to be here, there and everywhere, or appear to be this and that all at once – until you look at them. Then the quantum haze is suddenly distilled into something definite and describable, a thing we recognise as "real".

That much we know. The trouble is that quantum mechanics, the theory that describes this uncertain world, has been mostly silent about how the so-called "collapse" from fuzzy probabilities to solid certainties happens. Some physicists prefer to avoid the question altogether. Others suggest that we need to add something new to complete our understanding of how our familiar physical reality emerges from the quantum.

But what if the whole picture was there all along, and we just weren't looking carefully enough? That's the startling suggestion from recent experiments that have, for the first time, given us a glimpse inside collapse as it happens. Physicists are still coming to terms with what they have witnessed, and it is too early to say for certain what it all means. But already there are hints that the latest results could finally point the way towards the truth about how the world we know is conjured from the quantum realm.

Quantum theory enjoys exalted status in science because it describes the microscopic world with peerless accuracy. It was developed in the 1920s to explain why subatomic particles, such as electrons, seem to sometimes behave like waves, while light waves can show particle-like behaviour – and why their energies are limited to particular values. Physicist Erwin Schrödinger was one of those who did the maths. He devised an equation that describes such equivocal behaviour with a mathematical entity known as the wave function. This allows you to calculate reliably the odds on which of the various possible properties, such as location, will be observed if a quantum object is measured.

A decade later, John von Neumann introduced the idea that became known as wave function collapse: that the selection of a single outcome on measurement from all the possibilities encoded in the wave function happens randomly and instantaneously, even though repeated measurements of the same thing fit the odds predicted from the Schrödinger equation. That picture of a sudden, mysterious shift from many possibilities to one is often identified with the "Copenhagen" interpretation of quantum mechanics. That is despite the fact that Niels Bohr, one of the main architects of that interpretation, preferred to avoid entirely the question of what happens when we make a measurement.

There is no theoretical justification for wave function collapse as the correct way to describe what happens when we make a measurement, nor any explanation of what collapse is. Von Neumann just imposed it as a way of plucking a unique result out of the Schrödinger equation, and in doing so papered over a huge hole at the heart of quantum theory.

Collapse is "an inherently mysterious notion", says Zlatko Minev at Yale University. "It pulls a blanket over what a measurement is and the process by which a measurement changes the state of a quantum system."

It isn't surprising, then, that quantum theorists have come up with various ideas about what is going on beneath the blanket. In the many worlds interpretation, for instance, wave function collapse isn't necessary. It says that when a measurement is made, all possible outcomes contained in the wave function are realised in many separate worlds that branch off from ours at the moment of measurement so that there is a split rather than a collapse. In another interpretation, often known as Bohmian mechanics, the wave function is a kind of spread-out force that guides a single underlying reality in which particles always have definite properties and positions that are described by variables we can't access.

Then there is an approach known as "objective collapse" that says wave function collapse is a real, physical process – albeit a random one – and adds an extra bit to the Schrödinger equation to account for that.

All such solutions have their own

›

> "The founders of quantum theory dreamed of performing experiments like this one"

problems, which explains why physicists have been arguing vehemently and largely fruitlessly for decades about which is best, without any hard evidence to help them decide. This is exactly what Minev and his colleagues sought to rectify last year with an ambitious experiment designed to probe quantum measurement more sensitively than ever before.

To understand their results, they turned to a lesser known formulation of quantum mechanics known as quantum trajectory theory, or QTT. It was developed in the 1990s to track the path that a quantum object takes through the space of all its possible states as it is measured. "QTT is a wonderful, and widely used, tool for describing quantum evolutions," says Max Schlosshauer at the University of Portland in Oregon.

There is nothing in QTT that deviates from regular quantum mechanics. But it does have a unique selling point. Unlike the Schrödinger equation, which only describes a quantum system in isolation, it can describe the way quantum objects interact with their environment, dispersing their quantum-ness in a process known as decoherence, and getting jostled by the environment in return in another process known as back-action. Minev considers QTT "a refined and evolved version of quantum mechanics".

The trouble is that QTT is maddeningly difficult to use for analysing experiments because you need to know pretty much everything that happens. Imagine, for instance, attempting to monitor an atom that might make a quantum "jump" between energy states, emitting a photon of light as it does so. To apply QTT, you need to keep checking at incredibly short time intervals to see if the photon has been emitted. You can't afford to miss a single photon. And every time you check, you must consider the effect the resulting back-action has on the atom. It is hard to overstate how difficult that is. "Until now, the timescale at which jumps or collapses occur has been too fast to measure," says Minev.

That has now changed thanks to a team led by Minev's PhD supervisor Michel Devoret, and including theorist Howard Carmichael at the University of Auckland, New Zealand, who helped develop QTT. They used

Quantum corrections

The mysterious process by which the fuzzy, undecided quantum world snaps into the familiar certainties of "classical" physical reality was always thought of as a one-way street. But maybe not for much longer.

The physicists behind a recent experiment that gave us a first glimpse inside this process (see main story) now think they might be able to reverse it too – a feat that could boost the quest to deliver useful quantum computers, which exploit the strange properties of quantum physics to speed up certain calculations.

Last year, Google claimed to have reached the milestone of making a quantum computer that can solve a problem in minutes that would take the best conventional computer thousands of years. But one of the biggest hurdles to quantum computers routinely solving real-world problems is that it is hard to correct for errors that inevitably occur when a quantum bit, or qubit, which is the core component of a quantum computer, randomly flips its state – from a 1 to a 0, say. There is always a chance of such errors happening in the delicate quantum state of the qubits used for computation, and they create "noise" that can derail a calculation if they aren't corrected.

By catching a similar transition known as a quantum jump in the act, and anticipating when it was about to happen, Zlatko Minev at Yale University and his colleagues have suggested a possible solution. The idea is that, with sufficiently sensitive detection gear, you could monitor qubits so carefully that you could anticipate and immediately undo errors, or even prevent them.

According to Minev, the method "gives us the potential to intervene in the process by which noise occurs in a quantum computer, allowing us to potentially reverse it before it can muck up an entire computation".

William Oliver, an experimental physicist at the Massachusetts Institute of Technology also sees the potential. "Provided there is a signature that indicates a jump is about to occur," he says – one that doesn't actually reveal the information in the qubit, which would destroy the quantum-entangled qubit state on which the computation depends – "then one can imagine correcting for such jumps as they happen."

Other error-correcting techniques are already being developed, but this one could tackle the problem at its source.

Today's quantum computers are delicate and error-prone

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New experiments seem to undermine the "many worlds" take on quantum theory

superconducting quantum bits like those in quantum computers to build an artificial atom and watch it jumping from one energy state to another. They used microwaves to excite their "atom", then watched it emit microwave photons as it returned to its ground state.

In truth, what they were watching is a bit more complicated than that. The "atom" keeps jumping to the excited state and then, under the influence of the back-action caused by probing it, falling back down again. It doesn't "stick" in the excited state until a true quantum jump occurs. And now, for the first time, this jiggling back and forth could be tracked. "The founders of quantum theory dreamed of performing experiments such as the ones we can begin to perform now," says Minev.

What the researchers saw was a quantum jump unfolding over time: a phenomenon that turns out to happen smoothly, not suddenly as Bohr and his collaborators had assumed. The jumps occurred at random moments, but there was a kind of precursor signal when one was imminent: the jiggling caused by quantum back-action became unusually quiescent. Thanks to this advance warning of an impending jump, the researchers were even able to fire microwaves at the qubits to catch and reverse the jump as it was taking place, something never before achieved.

What does this have to do with collapse? Well, though it wasn't much remarked on at the time, the quantum jumps experiment was in fact also monitoring the process conventionally regarded as wave function collapse – because that is an inevitable consequence of continuous observation. In this case, as the artificial atom was continually driven towards one of its excited states, measurement kept collapsing it to the ground state. The same applied to the shift into an excited state. So the result implies that "collapse", too, is a real, physical and smooth process – an accumulation of small back-actions from continuous monitoring of the system – that can be seen as it unfolds.

The collapse of collapse

The work even raises the prospect of avoiding "collapse" altogether while making a measurement. This would mean controlling the interactions of a quantum entity with the environment so carefully that there is negligible back-action, and thus minimal disturbance. Such a measurement would supply information as precisely as could be, subject to the constraints of Heisenberg's uncertainty principle, which says there is a limit on how accurately certain pairs of properties can be measured. It would probe the system at the so-called "Heisenberg limit", free from any external back-action noise. That has long been a goal for extremely sensitive quantum detection methods, such as measuring photon travel times in a gravitational-wave detector, and it could have a serious role to play in making good on the promise of quantum computing (see "Quantum corrections," left).

"Given sufficiently powerful read-out hardware, we can make meaningful quantum measurements without collapse," says Devoret. "We are just a few years away from being in a position to do this kind of measurement."

In the meantime, the results that the team already have give us plenty to chew on – not least the implication that the notion of wave function collapse was never really necessary in the first place. It is just a crude way of talking about the change that occurs when a quantum system gets entangled with, and disturbed by, its environment. "The whole lexicon of 'collapse' is fatally flawed," says Minev. "It's a remnant of the discussions in the 1920s, and gives the wrong mental image. Quantum trajectory theory peels away the veil that has obscured the mechanics of collapse, and shows us there is no such thing."

That might sound radical, but it is supported by another recent experiment conducted by Markus Hennrich and colleagues at the University of Stockholm in Sweden, in collaboration with Adán Cabello at the University of Seville in Spain and others. They were able to perform a special, "ideal" kind of quantum measurement that doesn't destroy the quantum state (as it does when a photon is detected by being absorbed, for instance) but shifts it to another state that can be measured again. This applies even for superpositions: quantum states in which more than one possible outcome of a measurement is possible. Superpositions are normally destroyed by measurement, but they can survive an "ideal" measurement like this.

It has never been done before, but Hennrich and his colleagues pulled it off by measuring electrically trapped strontium ions. And again they saw a smooth, gradual change in state rather than the abrupt, destructive snap of conventional collapse. When properly used, says Cabello, quantum mechanics "describes measurement as a process that requires time and tells how the quantum state evolves". ›

“The idea that quantum measurement involves an almost magical transformation is now dead”

ASHLEY MACKENZIE

Where does that leave our understanding of how physical reality as we know it emerges from the quantum realm? For Hans Mooij, a specialist in quantum electronics at the Delft University of Technology in the Netherlands, experiments that reveal the fine details of measurement “will inevitably lead to a reinterpretation of quantum physics”, even if it isn’t yet clear what will emerge.

For starters, says Mooij, the work requires “a complete overhaul of the Copenhagen-related interpretation with collapsing wave functions” – neither Bohr’s “don’t ask” mantra nor von Neumann’s unexplained collapse seems needed any more. The idea that measurement involves some instantaneous, almost magical transformation is now dead, says Cabello.

Just add ignorance?

Removing the phenomenon previously known as collapse also seems to remove the key motivation for the many worlds interpretation of quantum theory, which seeks to avoid the need for collapse at the cost of proliferating worlds. “My personal view is that such an interpretation is redundant,” says Carmichael, but he admits “there is always wriggle room”.

In Carmichael’s view, what seems to be emerging is something not far removed from the objective-collapse picture, with the twist being that the random kick that forces a quantum system to decide on its state emerges naturally from the environment, rather than being added by hand as some putative, ad hoc mathematical extension of standard quantum theory. The equation of the most popular objective-collapse model, he says, “is formally equivalent to the version of QTT we used to model the Yale experiment” – with the random “collapse” term now coming from the inclusion of quantum back-action.

Arguably, that would remove the common objection to objective collapse – that bolting-on a new term to the Schrödinger equation is makeshift. But it isn’t that simple. For some supporters of this model, the add-on is essential and can’t be replaced simply with the inscrutably random influence of the environment. Without objective collapse, “there is nothing really random, but only ignorance about the exact state of the environment”, says Daniel Sudarsky at the Universidad Nacional Autónoma of Mexico. “And adding ignorance into the picture can’t possibly provide a better account of the state of affairs than not adding ignorance.”

Ultimately, says Sudarsky, making the environment the sole agent of collapse just postpones its origin to ever expanding definitions of the system: if you accept that the entire universe can be considered one big quantum system governed by the Schrödinger equation, there’s nothing left to collapse it.

Given the long history of argument over the right way to interpret quantum mechanics, it is too much to expect the debate to be settled easily. Theorist Roderich Tumulka at the University of Tübingen in Germany points out that QTT itself is agnostic about interpretations, which suggests it may be possible to formulate versions of Bohmian mechanics or many worlds that don’t conflict with these new observations. Indeed, some researchers insist that the new results have no consequences for the various ways to understand the meaning of quantum mechanics. For Lev Vaidman at Tel Aviv University in Israel, a long-term advocate of the many worlds idea, the Yale experiments “confirm that standard quantum mechanics and the equipment work well but have zero bearing on interpretations”.

Even if you aren’t partial to any of the exotic alternatives to Copenhagen, one thing at least is certain: Bohr’s insistence that the emergence of physical reality from the quantum realm is something that just happens, with no questions asked, is no longer an option. We can now watch measurement unfold, and we don’t need collapse to describe it.

The challenge now is to see if these new insights can be used to replace the magic wand of collapse with a full theory of quantum measurement. “I wish I was not retired and still in full experimental flow,” says Mooij, “because this will be extremely exciting.” ▮

Philip Ball is the author of *Beyond Weird: Why everything you thought you knew about quantum physics is... different*

Coronavirus

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Scroll down to be a better friend

A flurry of new apps promises to help us better manage our personal relationships. But do they work – and do we want them to, asks **Amelia Tait**

IT'S 8.18 am on a Wednesday when my phone buzzes with a prompt to "Offer your knowledge to others". The push notification also tells me that I have "three relationships to reach out to", including, in brackets, the name of my sister, and "four new people" to "discover" – here it mentions someone I recently emailed for work. I ignore it, then click snooze on several other reminders to reach out to my friends.

The message is from UpHabit, one of many apps that have launched in the past couple of years to help people better manage their relationships. They are based on customer relationship management software, or CRMs, which are now routinely used by companies for things like compiling customer data and offering up suggestions on how to retain business. These new apps, personal CRMs, offer similar services, but the relationships they help you "manage" are with your friends, family, colleagues and acquaintances.

In an era when people tend to move house or job multiple times, making and neglecting relationships as they go, these tools promise to help us stay in touch – and be better, more thoughtful friends. Yet how many people can we genuinely stay connected to? And if I send a message to someone because an app prompted me to, is it less meaningful somehow than if I remember myself?

To understand why so many personal CRMs, or PRMs, have popped up since 2018, what that says about our relationships and whether push notifications can really make us better friends, I gave a few a try. It didn't go quite as I expected.

If these kinds of apps sound tempting, you are currently spoiled for choice. From the least to the most inexplicably named, you can now download Ntwrk, UpHabit, Plum Contacts, Dex, Garden, Levitate, Monaru, Clay and Hippo.

They don't just prompt you to "discover new people" before you have had your morning coffee. Most work in a similar way: you import your contacts to the app, label and tag them as friends, family or co-workers, for instance, set reminders for when to contact them and log the topics you last spoke about. In theory, this means you will never forget the name of an acquaintance's kid or to ask your uncle how his knee surgery went, and you will generally have stronger, better relationships as a result.

"Everyone is very busy, and if you switch jobs or move continents, you kind of lose touch with people," says Neil Wainwright, UpHabit's founder. "I decided to build UpHabit because I wanted to help with that situation – I wanted to help people stay connected." When Wainwright first uploaded his contacts to the app, he was reminded of a colleague he worked with a decade ago. "I reached out to him, reconnected with him... and my wife and I actually went out for dinner with him and his wife, and it was a delightful time." They are still in touch.

> "These new tools promise to help us become better, more thoughtful friends to others"

Making it work

UpHabit is by far the most popular PRM on the market, something Wainwright attributes to his "obsession" with his customers. He says the app is constantly revised based on user feedback: in 2019, the team updated it 92 times, including enabling birthday reminders, adding a tab for recommended reading and allowing users to tag people in bulk.

Another thing that changes occasionally is the wording of push notifications, which Wainwright says have been refined. Still, compared with other apps, UpHabit's prompts have a slightly preachy tone: "Form great bonds by offering to help someone", "Nurture relationships before you need them", "A simple 'how are you?' can go a long way".

I didn't just ignore the "Offer your knowledge to others" notification, I actually laughed aloud. It felt strange and clinical to me, and the command seemed almost impossible to act upon ("Hi Beth, I know we haven't

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MICHAŁ BEDNARSKI

spoken in a while, but ideally you should caramelise your onions for up to an hour"). As well as UpHabit, I tried Dex and Ntwrk, but similarly struggled with their reminders. In a world of ever-increasing push notifications, it suddenly felt as though friendship had become another task to keep on top of.

On a practical level, I found Ntwrk's commands better and easier to act on than UpHabit's ("How about sending Allie a quick message?"). I also generally found its interface nicer, though its tutorial features characters from TV drama *Mad Men* in place of your contacts, which I found bizarre. Dex , a desktop application, was also visually pleasing as it uses emojis to help categorise people, but I found it buggy when importing contacts from Facebook. With each app, I set up reminders for who I wanted to contact and when, and got notifications when the time arose.

I thought these apps might be worth a try based on my own experience coming up short in a friendship. Towards the end of 2019, I forgot to text a friend to ask how her job interview went, remembering only weeks later when we went for dinner. I felt terrible, especially as I was one of the only friends she had told about the interview and because I had made a mental note to text her. This is just the kind of problem a PRM aims to solve. But why should we now need these digital reminders when, for centuries, we have simply relied on our brains, calendars and stray Post-it notes?

"Life is busier now for sure, and we move more, so relationships get disrupted by distance more often," says Robin Dunbar, an evolutionary psychologist and anthropologist at the University of Oxford. "I think this is why Facebook took off so suddenly – it caught a generation that was much more mobile and realised that this badly affected close relationships that they wanted to keep going."

In 2010, Dunbar wrote the book *How Many Friends Does One Person Need?* and posited that, cognitively, humans are only able to maintain 150 stable relationships, something now known as Dunbar's number. He says that, on average, we all have five intimate relationships ("shoulders to cry on"), 15 close friends and family, 50 good friends (the people you would invite to a party) and 150 friends (people who might turn up to your funeral). Dunbar hit upon these figures by studying different primate brains, including ours, and comparing them with social group size. Put simply, he concluded that our brains aren't big enough to maintain more friendships.

If our brains can't do it on their own, can apps help? Early into my experiment, a week-in-review update from UpHabit chastised me for only actively managing four friendships, saying the app works best when "enhancing 50+" relationships, with "top Habiteers" managing more than 300. Dunbar says it is unlikely that apps will allow us to foster more than 150 stable relationships, because "the constraint is in our heads" – although he does say we can have up to 500 acquaintances.

D.ANSCHUTZ/GETTY IMAGES

Beyond the mental limitations, Dunbar says we simply don't have enough time for more relationships. Apps can help with time management, by allowing you to reach out to two people at once, for instance, but they can't magically create more dates in the diary to have dinner, or renew our interest in someone we were naturally drifting apart from.

"We can all have about 150 friends. Our brains aren't big enough to maintain more"

Theoretically, then, while PRMs can't help us have more friends than ever before, they should be able to help us better maintain the relationships we have. Does this work in practice? Dunbar's research has shown that we usually have to see someone at least once a week to keep them in our top five friends, whereas once a month will suffice for the 15 close friends layer. "You have to see the whites of their eyes," he says. Historically, face-to-face meetings, storytelling, sharing food and drink and performing rituals have all been essential in-person interactions for maintaining friendships. Yet in the context of the ongoing global coronavirus crisis, just how well we can recreate these experiences using technology, and specifically video chat apps such as Zoom and Houseparty, is being tested like never before.

At any rate, most PRMs don't claim you should only reach out to friends via the internet – and on UpHabit, at least, you can log whether you chatted through text, email, on the phone or face-to-face. Yet when the prods to connect pop up, I found that I ended up throwing out a quick message, and was disappointed by the artificiality of the ensuing exchange. After two weeks, I started hitting snooze on notifications.

Lucas Bazemore, co-founder of a now defunct PRM called Ryze, sheds light on my difficulties. "Our customer retention was atrocious," he says. "People would start using it for about a week, and then they'd say, 'I don't really know what I'm going to get out of this'."

Bazemore was motivated to launch the app when he was at university because he realised he was likely to lose touch with friends after graduation. He also admits he had "grandiose" ideas about taking on LinkedIn.

He acknowledges that PRMs can be difficult to stay on top of for most people. "It's a lot of work," he says. "The benefit is too vague and too far into the future to justify all of the inputs required." The reason so many inputs are needed is because it is really hard to consolidate all the applications we already use – emails, calendars, Slack, WhatsApp, Telegram, phone logs – into a single PRM. The apps can also wind up feeling redundant. I didn't bother with birthday reminders in my PRMs because Facebook has done the job perfectly for years.

Another issue is whether we truly want to stay so connected. "By nature our relationships are ephemeral," says Bazemore. I'm happy to naturally let some relationships go – I don't want to keep in touch with everyone I met at university, for example. It feels strange to force friendships when it may be time to drift apart.

As such, I saw no immediate benefits from the apps, and the long-term benefits advertised felt weirdly transactional. For example, Dex's home page promises you can "turn the person at a networking event into someone who has your back". On a practical level, I also found that I remembered the appointments, anniversaries and anguishes of close friends, making the reminders redundant. Setting reminders for people I was less close with – to ask an acquaintance how a work project went, for instance – left me feeling more creepy than caring when I reached out. After all, how would people feel if they knew I was only chatting to them because an app told me to?

"Most of us have electronic calendars where we input our friends' birthdays, so an app isn't that far of a stretch from that concept. But if we are using software to remind us how to be a friend, that seems a little more mechanical," says Suzanne Degges-White, a professor of counselling at Northern Illinois University and author of *Toxic Friendships: Knowing the rules and dealing with the friends who break them*.

> "The reminders left me feeling more creepy than caring when I reached out"

Wainwright understands this criticism. He says he doesn't like to use the term "personal CRM" as it can be off-putting to the people who are being relationship managed. On a personal level, Degges-White says she would "like to think a good friend wouldn't need an app to remember that I'd just broken up with my partner or that I'd gotten a new dog last week".

Remember, remember

Despite my difficulties, many people swear by PRMs. Timothy Luoma, a Presbyterian pastor in Plattsburgh, New York, uses UpHabit to remember the details of his parishioners' lives, in particular, to keep track of death anniversaries. "The overall goal is to make sure that I am taking good care of my entire congregation, and not just those people who I see regularly, or the squeaky wheels," he says.

Luoma also uses reminders to call each member of his congregation on their birthday. "Phones are not new. Calendars are not new. So why didn't previous pastors call people on their birthdays? Well, if I had to use a calendar of birthdays and then had to look up people's phone numbers, I might not do it, or it might seem like a hassle," he says.

The more I use the apps, the more I am convinced they suit niche needs like Luoma's. It is also easy to see how PRMs could be helpful to people who have memory loss or who may struggle with social connection. At least anecdotally, for now the apps seem to be favoured by people whose careers rely on intertwining the personal and professional, and, unsurprisingly, early adopters of new technology.

When I ask Wainwright to put me in touch with UpHabit users, the first three people he refers me to all work in tech. Edmund White, who is at a software company in Brooklyn, tells me that before downloading UpHabit he kept a spreadsheet of his acquaintances after learning that networking is crucial for success. "I knew this was one of my weak points and something I was not comfortable with," he says. White maintains 58 relationships in UpHabit. Ironically, using the app has made him need it less. "I now think about others and will sometimes follow up without being prompted by the app," he says.

Despite the hype, the number of people using PRMs remains small. UpHabit has just over 25,000 downloads. Bazemore says Ryze was downloaded less than 10,000 times and Dex's operations are so small that its founder Kevin Sun sent me a personal email offering to show me the ropes after I signed up. Later, he told me this unusual move provides crucial feedback for making the product better.

In truth, PRMs have been popping up since 2011, says Bazemore. "Once every six months some venture capitalist on Twitter will have a tweet storm about PRMs and everybody in college thinks, 'Oh, I can build that'," he says. Most of Ryze's biggest competitors when it launched in 2017 are also now defunct. "We had a list of about 10 that existed two years ago – they don't exist now."

Ultimately, it feels as though PRMs reveal less about modern friendships and more about the frenzied start-up culture trying to optimise every area of our lives. I don't doubt these apps are useful for some people, I'm just not one of them. How's that for offered knowledge? ■

WOLFGANG STEINER/PLAIN PICTURES

Without meeting regularly in person, friendships inevitably grow more distant

Amelia Tait is a writer based in London who specialises in digital culture. Follow her @ameliargh

You're only as young as your immune system

There has never been a more important time to keep your immune system fit and healthy. And as **Graham Lawton** discovers, there are now ways to keep it younger than you are

FRANCESCO BONGIORNI

WASH your hands religiously for 20 seconds, sneeze into your elbow, avoid touching your face, stay 1 metre away from all other people and, as a last resort, self-quarantine for a week with only your emergency rations for company. If you want to avoid getting the new coronavirus, all of these are a good idea. But ultimately, one of the most important things standing between you and a deadly bout of covid-19 is your immune system.

We know that the immune system gets weaker as we age – which is a key reason why those over the age of 70 are most at risk from the disease. But what is becoming clear is that when it comes to immune health, age is just a number. Some people have an immune system that is effectively significantly older or younger than they are. "Some 60-year-olds have the immune system of a 40-year-old, some are more like an 80-year-old," says Shai Shen-Orr, an immunologist at the Technion-Israel Institute of Technology. The good news is that there are some simple ways to turn back the immunological clock. Because even after the threat of this virus has passed – sooner or later another one is going to come along, and none of us is getting any younger.

As anyone who has studied immunology will tell you, the immune system is immensely, mind-bogglingly intricate. "It is the second-most complicated system in your body after your brain," says Shen-Orr. It consists of hundreds of cell types and signalling molecules controlled by some 8000 genes, interacting in a network of near-infinite complexity.

Happily, you don't need to know all of its intricacies to take advantage of the latest developments in immunology – although a little knowledge can help (see "Immunology at a glance", page 47).

If you are younger than 60, in good health and don't have too many bad habits, then your immune system is probably functioning well enough to keep you safe from almost any infectious disease, including coronavirus.

The bad news is that as we age, our immune systems gradually deteriorate too. This "immunosenescence" starts to affect people's health at about 60, says Janet Lord at the University of Birmingham, UK. The older you get, the weaker your immune system becomes, and the more likely you are to get seriously ill or die because of it.

During a typical winter flu season, for example, very few people under the age of 65 get ill enough to be hospitalised. About 20 per cent of those aged 65 to 74 who catch the disease do, although hardly any of them die. But among the over 75s, about half of those with flu end up in hospital and 30 to 40 per cent of them die. Most of those who pull through never fully recover. Similar hospitalisation and mortality rates are being seen with the coronavirus, says Lord. As with flu, the difference for most people is down to immunosenescence.

To many, immunosenescence may sound like a far-off threat, but it is something that should concern us all. The decline starts surprisingly early in life, during puberty, and can be accelerated by all kinds of lifestyle

factors. People who smoke or who are obese are particularly likely to have an immune system that is older than their chronological years. Being sedentary is another risk factor.

This has led to a new concept called immune age. It is similar to biological age, which uses chemical tags progressively added to genes throughout life to measure how far down the trajectory of ageing somebody has travelled, regardless of the number of years on the clock. Biological age and chronological age are usually quite tightly coupled, but can diverge by as much as 20 years either way. And unlike chronological age, biological age can go down as well as up, usually as a result of deliberate lifestyle changes. Both, it turns out, are also true of immunological age.

This way of thinking about the immune system has many uses. Knowing our immune age could help doctors judge how susceptible we are likely to be to illness. It might also help us all to maintain and strengthen our immune system. For instance, it could be used to validate supposed immune-boosting strategies. Does it affect immune age? If not, think twice.

"At 60, some people have the immune system of a 40-year-old, others an 80-year-old"

Until very recently, it was impossible to measure immune age. But last year, a team led by Shen-Orr and Mark Davis of Stanford University in California revealed a way to do it. Using a "multiomics" approach – looking at a person's genome, immune system, and protein function – the researchers audited the immune systems of 135 people in two age brackets, 20 to 31 and 60 to 96. They then repeated the measurements several times over nine years. What they discovered was that human immune systems follow a predictable trajectory. "We can give you a number which says where are you along this trajectory. That is your immune age," says Shen-Orr. "And it is a very good predictor of all-cause mortality."

Immune age measurement is still new and there is no commercially available test, although the team is working on one. ›

THE IMMUNE DIET

One of the most successful anti-ageing strategies ever discovered is caloric restriction. It requires a permanent cut in energy intake of up to 60 per cent. In every experimental animal that has been put through this, from fruit flies to primates, it extends lifespan and healthspan, the number of disease-free years at the end of life.

The strategy works because it switches on an evolutionary adaptation to starvation, which prioritises repair and survival pathways over growth and reproduction. Calorie-restricted animals tend to be leaner, fitter, metabolically healthier and mentally sharper than those that eat at will. They also have a stronger immune response.

Unfortunately, caloric restriction is extremely hard to maintain voluntarily. But there are ways to mimic it without going on a permanent starvation diet. The key is to deactivate a nutrient-sensing pathway inside cells called mTOR. When calories are scarce, it switches off, initiating the metabolic cascade that transitions your system into famine mode. The pathway can also be toggled off with drugs called mTOR inhibitors, the best-known being rapamycin.

The strongest evidence that it is an immune booster comes from a clinical trial by the biotech company resTORbio, based in Massachusetts. One of its targets is immunosenescence, the gradual decline of our immune systems with age (see main story). Last year, the company ran a placebo-controlled study of a rapamycin-like mTOR inhibitor on people over the age of 65 who received a dose just before a flu vaccine. Those given the drug showed a stronger response to the injection and an uptick of their antiviral gene expression. "Some aspects of immune function are clearly getting better," says Joan Mannick, resTORbio's chief medical officer. The drug has since failed a phase III clinical trial for reasons that are still unclear. Yet Mannick – and other researchers not involved in the work – say the principle that mTOR inhibitors can treat immunosenescence still stands.

CUTTING CALORIES

Some people self-medicate with rapamycin even though it isn't officially recognised as an anti-ageing or immune-boosting drug. There are other ways to achieve mTOR inhibition though. One is intermittent fasting, a temporary state of caloric restriction that is enough to switch off mTOR for a short while and still obtain its benefits. There are various regimes including the 16:8 diet, which involves completely eschewing calories for 16 hours and only eating in an 8-hour window. Even done once a week, this is an effective way of slowing ageing and strengthening the immune system. Exercise is also a proven mTOR inhibitor.

Even if a fasting diet isn't for you, simply keeping your weight down can have immune-boosting effects. According to Bonnie Blomberg at the University of Miami in Florida, being obese suppresses the immune system to a similar extent as being immunosenesced. Ageing is associated with a decline in the function of the immune system's B-cells and low production of antibodies in response to vaccines, and so is being obese. "Adipose tissue negatively impacts the antibody response," says Blomberg. "So obesity is associated with poor vaccine response, even in people who are young."

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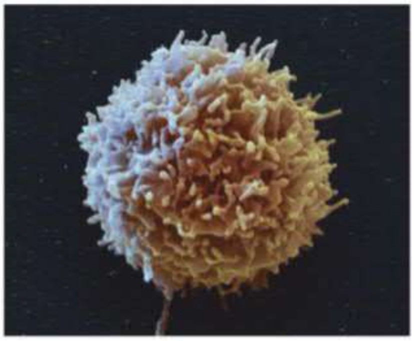

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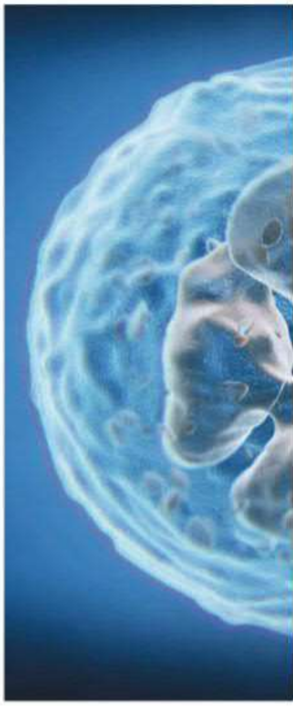

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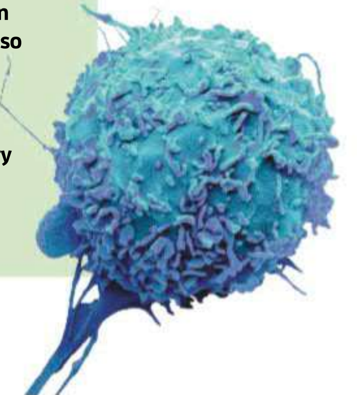

STEVE GSCHMEISSNER/SCIENCE PHOTO LIBRARY

The immune system has many defenders, including dendritic cells (top left) and a range of white blood cells that seek out and gobble up or kill invaders

For now, probably the best way to gauge your immune age is to get your biological age tested, because the two seem to be roughly correlated.

Regardless, you don't need to know your immune age to take steps to start lowering it. And it turns out that many of the emerging anti-ageing drugs and strategies do their stuff, at least in part, by arresting or even reversing immunosenescence.

One key approach to keeping our immune age down relates to the fact that as we get older, some of our immune cells start to misbehave. This is especially problematic for a class of immune cells called neutrophils, the most common type of white blood cell. These form part of the innate immune system, the body's first line of defence against infection, and are the border force of the immune system, patrolling tirelessly through the bloodstream on the lookout for harmful bacteria. When they detect an intruder, they squeeze out of the blood vessel and barrel towards their target, then take it out in one of three ways: engulfing it like Pac-Man, spraying it with deadly chemicals or suicidally disgorging their DNA and throwing it around the invader like a net.

The process by which they tunnel through tissues is called chemotaxis, and it becomes increasingly erratic as we age. Older neutrophils can still detect invaders, but become much worse at hunting them down, often blundering haphazardly through tissue

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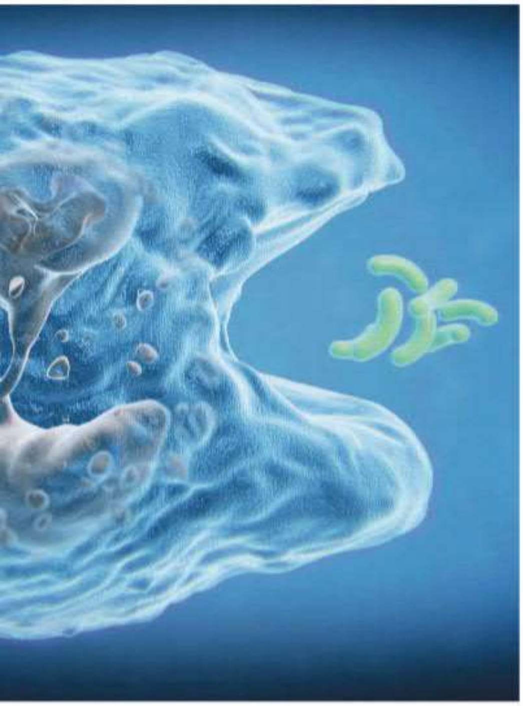

> **“Taking small daily doses of vitamin E may help rejuvenate immune cells”**

or charging off in the wrong direction. “I always say they’ve lost their satnav,” says Lord.

This is problematic for two reasons. It reduces the speed and efficiency of the defence, giving invaders more time to gain a foothold. It also causes inflammation. Lord has found that the blundering neutrophils cause between two and five times as much damage as their comrades that still know their way. Such friendly fire is a leading cause of inflammaging, the generalised low-level inflammation that creeps throughout our bodies as we age.

But the neutrophil satnav can be reset. The root of the problem is a chronically overactive enzyme involved in directional control. So Lord tracked down some existing drugs that were known to dial down this enzyme. When she gave one of these drugs to older adults, she found that it reset their satnav. “Their neutrophils are rejuvenated, they move like a young person’s neutrophils,” she says.

What are these miracle drugs? Statins, the ordinary cholesterol-lowering drugs already taken by millions of people.

Turning to real patient data from the University of Birmingham’s Queen Elizabeth hospital, Lord found that people admitted to hospital with pneumonia were much less likely to die if they were already taking statins to lower their cholesterol. This staggering result has since been confirmed in a small clinical trial. It is too early to recommend that everybody takes statins as an immune booster, says Lord – she and her team are conducting a bigger clinical trial. The drugs can also have serious side effects. But now might be a good time to have your cholesterol levels tested, once your local health system has capacity.

There is also a drug-free way to rejuvenate your neutrophils: exercise. In 2016, Lord and her colleagues measured exercise levels and neutrophil migration in 211 older adults. “Those doing 10,000 steps on average had neutrophils as good as young adults,” she says. She emphasises that neutrophils aren’t antiviral so won’t prevent you catching coronavirus or help you beat it, but they will protect you from the real danger, which is pneumonia. “Usually what carries people away with these [viral] infections is secondary infections,” she says.

Vital vitamins

Another class of immune cells that begin to misfire as we age are T-cells. These are pivotal in the adaptive immune response – the more targeted part of the system – but are blunted in two ways by immunosenescence. As with neutrophils, their internal signalling pathways go awry, and they are also inhibited by inflammaging. But there may be a simple way to undo this damage. According to Dayong Wu, a nutritional immunologist at Tufts University in Boston, the answer is vitamin E.

In animal studies, it has long been known to enhance immune function, but the relevance of this research to humans was overshadowed by studies suggesting that vitamin E supplementation is toxic. Wu now says this is irrelevant: toxicity only arises at doses double that needed for T-cell rejuvenation. He and his colleagues tested vitamin E in older people – giving half of the 670 residents of a nursing home a small daily dose of vitamin E and the other half a placebo – and found significant differences in the rate of upper respiratory infections. A bigger clinical trial is in the pipeline, but the evidence is already strong enough that Wu recommends people over 65 routinely take 200 international units (IUs) of vitamin E. “It may help immune function. It doesn’t hurt,” he says.

Vitamin D, meanwhile, appears to do the same for the innate arm of the immune system, especially among people living at latitudes where there isn’t enough winter sunlight for their skin to synthesise the molecule. A 2017 review of the evidence for taking vitamin D supplementation concluded that it prevents upper respiratory tract infections. About 1000 to 2000 IUs should be safe and beneficial, says Wu, but people shouldn’t go higher than that because big doses actually suppress T-cell function.

A third supplement with good evidence for immune-boosting powers is zinc. “It is very effective for viral infections,” says Wu. Though he adds, “be cautious, the effective window is narrow and an overdose will suppress your immune system”.

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IMMUNOLOGY AT A GLANCE

There are two basic arms of the immune system: innate and adaptive.

Innate immunity is the first line of defence, staffed by general-purpose, pathogen-killing cells such as neutrophils and macrophages. These are the early responders to an invasion. The adaptive side is more targeted and slower, reacting to specific pathogens with precision weapons such as T-cells, B-cells and antibodies. The adaptive arm also provides immune memory, which prevents you from getting certain diseases twice.

Cells called memory B-cells recognise the pathogen and trigger a swift and ruthless response if it invades again. Some viruses – notably flu – can mutate to evade immune memory. We don’t know yet if the new coronavirus does this.

DO SOME PEOPLE NATURALLY HAVE A STRONGER IMMUNE SYSTEM?

Even among people with a fully functioning immune system there are significant differences in how well it works. In 2018, the Milieu Intérieur Consortium based at the Pasteur Institute in France scrutinised circulating immune cells from 1000 men and women aged between 20 and 69. They found major individual differences between people of different ages, which you would expect given that the immune system declines as we get older. But they also discovered that people of the same age can have very different immune systems, beyond variation in their so-called immune age.

This is partly down to varying lifetime exposure to viruses and bacteria, which can radically alter the composition of your adaptive immune system – the wing of your defences that produces antibodies targeted to attack threats.

Genetics is also key. The Pasteur team found big disparities in the composition of people's innate immune systems, the generalised first line of defence, and these mapped onto differences in their genes. The significance of these genetic variations in immune response isn't yet known, but it may be that some people are naturally better than others at dealing with certain threats. Like a lot of things in life, immune strength is a genetic lottery.

Beyond genetics, the team found that smokers have a much older immune profile than non-smokers of the same age. It's unknown if this is reversible. But if you don't want to prematurely age your immune system, it would be best not to smoke.

Similar research on immune ageing by researchers led by Shai Shen-Orr at the Technion-Israel Institute of Technology suggests that the immune system can burn out. They tested the immune age of children living in Bangladesh, who generally have a heavy burden of infectious diseases and parasites, and found it was similar to that of young adults in California. The long-term clinical relevance of this is unclear, but it seems to undermine the adage that "what doesn't kill you only makes you stronger".

That said, an underworked immune system also seems to be problematic: people who aren't exposed to infections and parasites in childhood seem more susceptible to autoimmune disorders such as allergies later in life.

Aside from misbehaving immune cells, another big clue about the demise of our immune system with age comes from a vital but little-known organ called the thymus that is (or was) located beneath your breastbone. This heart-shaped patch of lymphatic tissue is where new T-cells mature before being released on active duty. It is very active in childhood but degenerates with age, shrinking by about 3 per cent a year from the onset of puberty. By late middle age, it has usually been reduced to a few scraps, and T-cell counts fall off a cliff.

This has consequences for the ability to fend off novel pathogens. In older people, who barely have any thymus left, the adaptive immune system is severely diminished, leaving an entire flank of their immune defences horribly exposed.

WILDPIXEL/GETTY IMAGES

Regenerating the thymus, which wears down with age, can refresh the immune system

Step it up

Thymic regeneration is an active area of anti-ageing research. Some people have attempted to regenerate their own using human growth hormone. But there are non-pharmacological interventions. In 2018, Lord and her colleagues published a study of 125 amateur cyclists aged between 55 and 79. Most had been regularly riding long distances for decades. Unsurprisingly, they were leaner, fitter and stronger than average, but they also had better immune systems. Their T-cell counts were similar to those of much younger people and their thymuses were youthful. "A large part of thymic decline is down to physical inactivity," says Lord. There are strong suggestions from animal experiments that exercise might not just prevent thymic degeneration, but also reverse it, although that hasn't yet been demonstrated in humans.

Exercise has other immune-boosting effects too. "Active skeletal muscle is anti- inflammatory and stimulates macrophages," says Lord, who goes running every day. "Skeletal muscle is a profound immunoregulatory tissue in the body and keeping it going by physical activity really will have a lot of benefits for health. Exercise benefits all ages." Asked what one thing she would recommend to strengthen your immune system, she says: "Increase your step count to 10,000 per day." In the face of the new coronavirus, it is more important than ever to find ways to stay active – even in lockdown or isolation, which isn't going to be easy.

What you eat will also matter to your immune system – now is the time to look after your gut flora. There is good evidence that probiotics can enhance the immune system, that poor gut health is a cause of premature ageing and even that a healthy microbiome can reduce your immune age. In as-yet unpublished work, Lord's team analysed patients with the diarrhoea-causing gut pathogen *Clostridioides difficile*. Their immune age was off the scale, she says, 10 to 20 years higher than their chronological age. But after they were given a faecal transplant from healthy younger donors, it dropped rapidly. "The reduction is amazing, literally within a couple of weeks," says Lord.

You may not want to try that one at home. But there is plenty you can do to maintain a robust gut flora, including eating a healthy, varied diet rich in fibre, plant matter and fermented foods such as kimchi. Other dietary changes, such as fasting, are backed by good evidence too (see "The immune diet", page 46).

None of these interventions is without sacrifice. But if you want to stay alive and well for as long as possible, looking after your immune system is a no-brainer – especially now the new coronavirus is being called the biggest threat to public health since the 1918 flu. "The age of your immune system is a critical component of your lifespan," says Shen-Orr. "Think about what the system is supposed to do!" ■

Graham Lawton is a feature writer and columnist at *New Scientist* and author of *This Book Could Save Your Life*

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Marine Biological Laboratory

THE UNIVERSITY OF CHICAGO

The Ecosystems Center of the Marine Biological Laboratory (MBL) is hiring faculty at all levels to expand our program in coastal ecosystems ecology. Scientists with an interest in collaborative, interdisciplinary studies on coastal estuaries, bays, marshes, and/or coastal watersheds across the globe will be considered. Applicants from communities underrepresented in science, or with a strong history of service to these communities, are particularly encouraged. Candidates applying at the Associate or Senior level should demonstrate the potential to take a leadership role in the Plum Island Ecosystems Long-Term Ecological Research program (pie-lter.ecosystems.mbl.edu/) or the Semester in Environmental Science (mbl.edu/ses/). We seek candidates with diverse areas of research expertise, including, but not limited to, biogeochemistry and its controls, trophic interactions, ecological modeling, and community and ecosystem ecology. Top priority will be given to candidates demonstrating interest in conducting research within the broad context of global climate change and other anthropogenic influences on the coastal zone.

The Ecosystems Center (mbl.edu/ecosystems/) was founded four decades ago to investigate the structure and functioning of ecological systems and predict their responses to changing environmental conditions. The current faculty is highly collaborative, with strength in biogeochemistry, ecological modeling, microbial ecology, microbial dynamics, plant-soil interactions, coastal processes, and adaption to life on land (mbl.edu/ecosystems/faculty/). Ecosystems faculty also collaborate with other groups at MBL with expertise in molecular evolution, functional genomics, microbial diversity, developmental and regenerative biology, bioinformatics, and advanced imaging techniques. MBL's initiative in coastal ecosystems ecology complements other strategic initiatives at MBL involving microbiome research, the development of aquatic organisms as new research tools, and advanced imaging and image analysis. The MBL is an affiliate of the University of Chicago and an Equal Opportunity/Affirmative Action employer committed to diversity. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, disability, gender identity, sexual orientation or protected veteran status.

Qualifications:

Applicants must hold a Ph.D. (or equivalent advanced degree) in a relevant field. The successful candidate will demonstrate an interest in collaborative, interdisciplinary work, as well as a strong potential for establishing a vigorous extramurally supported research program that can complement existing areas of strength.

Applications should be submitted at **https://academicjobsonline.org/ajo/jobs/15843**

Applications received by March 15 will receive full consideration; however, applications will be accepted until the position is filled. Inquiries about the position should be directed to Dr. Anne Giblin, Chair of the Search Committee **(agiblin@mbl.edu).**

Northeastern University

Assistant/Associate/Full Teaching Professor - Electrical and Computer Engineering - Robotics

About the Opportunity:

The Department of Electrical and Computer Engineering at Northeastern University invites applications for Assistant/Associate/Full Teaching Professor with a focus on Robotics

Responsibilities:

Northeastern University's Department of Electrical & Computer Engineering seeks outstanding candidates for the position of Assistant/associate/full teaching professor with a focus on Robotics. This is a full-time, benefits-eligible, non-tenure-track position. Appointments are made on an annual 8-month basis, with salary commensurate with experience. The position of Assistant Teaching professor entails educational interaction with students in roles including, but not limited to, traditional instruction (lecture courses, lab courses), curriculum development, and student advising. The main responsibility of this position is teaching courses related to robotics, including kinematics, dynamics, and control of robots, design of microprocessor-based control systems, sensory devices, output actuators, numerical methods, state estimation, control, perception, localization and mapping, motion planning, and the ROS (Robotic Operating System) environment. Also expected to teach courses in embedded systems, digital logic design, computer organization and/or programming.

The annual teaching course load is six courses, with the potential for teaching more than one section of a course in the same semester, over Fall and Spring semesters. Courses may be at both the undergraduate and graduate levels.

Qualifications:

A PhD in Computer Engineering, Electrical Engineering, Computer Science, teaching experience, is required. Candidates should have demonstrated experience robotics and related subareas. At least 2 years' experience in teaching at the college/university level is recommended. Excellent written and oral communication skills are required. Industrial experience is desirable, but not required.

Application should include a cover letter, CV, teaching statement, 3 references. A sample syllabus from a previously taught class is optional but recommended.

Salary Grade: FAC

Additional Information:

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To learn more about Northeastern University's commitment and support of diversity and inclusion, please see www.northeastern.edu/diversity

To apply, visit https://apptrkr.com/1784885

The back pages

Puzzles
Quick crossword, a change challenge and the quiz p52

Feedback
Odd social distancing tips; rise of the bidet – the week in weird p53

Twisteddoodles for *New Scientist*
A cartoonist's take on the world p53

***Almost* the last word**
Sleep trackers and the seat of wisdom: readers respond p54

The Q&A
John Troyer on technology and dead bodies p56

Science of cooking Week 13

Become a pastry whizz

Master the principles of a perfect pie dough and you will never again feel worried about making it, says **Sam Wong**

Sam Wong is social media editor at *New Scientist*. Follow him @samwong1

What you need

Pastry:
250g plain flour
125g cold butter
25g icing sugar
3 tbsp milk
salt

Filling:
400g rhubarb
200g caster sugar
75g butter
2 eggs
125g ground almonds

MANY amateur cooks, even quite confident ones, find making pastry intimidating, but making a good pie or tart isn't that hard once you grasp the basic concepts.

When flour is mixed with water, proteins in the flour link together into long strands called gluten that can make dough springy. With pastry, unlike bread, the objective is usually to limit gluten by using low-protein flour, less water and little kneading. This helps to create tender and flaky textures. Any sugar or acid added to the dough will also inhibit gluten formation.

The way that fat is incorporated into the dough plays a big part in determining the texture of pastry. In shortcrust pastry, fat is worked in to coat the flour particles and stop them from becoming hydrated. A little water or milk helps the dough come together, but the fat inhibits the formation of a gluten network.

In puff pastry, cold butter is incorporated into the flour so that much of it stays in distinct layers, separating thin layers of dough. Butter is around 16 per cent water. In the oven, the water evaporates quickly, pushing apart layers of dough and creating a flaky texture.

For both kinds of pastry, you must be careful not to overwork the dough, or you will warm the butter and make it release water. This will result in excessive gluten and a chewy, tough result. That is why pastry chefs use cool marble worktops and chill their tools. Vegetable shortening is more forgiving than butter, but doesn't melt in the mouth or taste as good.

PATNOWA/GETTY IMAGES

Science of cooking online
All projects are posted at
newscientist.com/cooking **Email: cooking@newscientist.com**

When it comes to choosing a recipe, rhubarb tart is one of my favourites. In the UK, rhubarb season begins in April, but before then you can buy forced rhubarb. These plants are kept in the dark, making their stems grow quickly in search of light. This gives them a sweet taste and a rich red colour.

To make the shortcrust pastry for the tart, mix the flour, icing sugar and a pinch of salt. Cut the butter into cubes and rub it into the mixture with your fingertips until it resembles breadcrumbs. Add just enough milk to form the dough into a ball, wrap it in plastic and chill it for an hour.

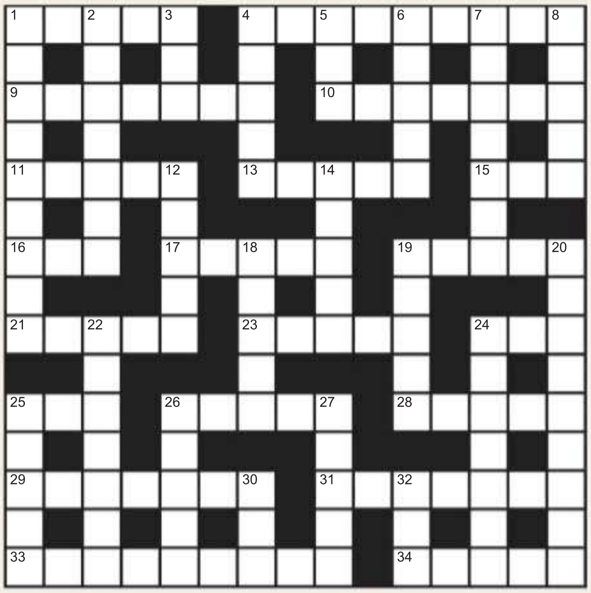
Grease a 26-centimetre tart case. On a floured surface, roll the dough into a circle that is about 3 millimetres thick, then press it into the case and poke holes all over the base with a fork. Place a piece of greaseproof paper on the pastry and fill the case with baking beans or uncooked rice to stop the pastry base from rising. Bake for 15 minutes at 180°C, then another 15 minutes without the paper and beans.

Cut the rhubarb into pieces 4 centimetres long. Toss with 75g of sugar and leave for an hour to absorb sugar and release moisture. For the filling, mix the butter and 125g of sugar, then mix in two eggs and 125g of ground almonds. Spread this into the pastry case, then press the rhubarb pieces into the filling, arranged artfully. Bake for 35 minutes at 180°C. ▮

Next week

Crackling: what is the path to perfectly crunchy pork skin? We test four techniques.

Quick crossword #54 *Set by Richard Smyth*



ACROSS

1 Greater (5)
4 Administration by syringe (9)
9 Lego range launched in 1982 (7)
10 Dry skin (7)
11 3 (5)
13 Waxy skin secretion (5)
15 Laugh out loud (3)
16 Gene that codes for regucalcin (3)
17 Minor proposition in mathematics (5)
19 Poisonous element in snake venom (5)
21 ___ Hubble, astronomer and cosmologist (5)
23 Primary colour (5)
24 IT manager (3)
25 Female, for example (3)
26 Spreadsheet software (5)
28 Device using negative feedback to correct the action of a mechanism (5)
29 International Bureau of ___ and Measures (7)
31 Concept in mathematical analysis (4,3)
33 Governing device; supervisory body (9)
34 UK maker of computer peripherals (5)

DOWN

1 Mathematics picture book by Jon Scieszka (4,5)
2 ___ cuckoo, *Clamator jacobinus* (7)
3 Operating command (3)
4 Anvil (5)
5/14 Sophia ___, first practising female doctor in Scotland (3-5)
6 Compact disc read-only memory (2-3)
7 Anabolic hormone (7)
8 Of the nose (5)
12 Enemy of humanity in TV show *Battlestar Galactica* (5)
14 See 5 Down
18 "Any sufficiently advanced technology is indistinguishable from ___" – Clarke's first law (5)
19 ♀ (5)
20 Part of mammal brain (9)
22 Migratory songbird, *Bombycilla garrulus* (7)
24 Magnus ___, chess grandmaster (7)
25 Effluent evacuator (5)
26 ___ group, $-CH_2CH_3$ (5)
27 Of the moon (5)
30 Single electron transfer (3)
32 Combat among male grouse (3)

Answers and the next cryptic crossword next week.

Quick quiz #44

1 NASA's COBE satellite, launched in 1989, was the first to make detailed measurements of what?

2 With what recent breakthrough in genetics are the names Emmanuelle Charpentier and Jennifer Doudna associated?

3 *Rumex obtusifolius* to counteract the effects of *Urtica dioica*. What?

4 6, 28, 496, 8128 … what sequence of numbers is this?

5 In organic chemistry, what is the name of the process of splitting complex molecules such as long-chain hydrocarbons by breaking carbon-carbon bonds?

Answers below

Cryptic Crossword #27
Answers

ACROSS 1/4 Alice Springs, **8** Fission, **9** Bagel, **10** Lei, **11** Upholster, **13** Crewed, **14** Strafe, **17** Recondite, **19** Gel, **21** Own up, **23** Rainbow, **24/25** Looking glass

DOWN 1 Awful, **2** Inspire, **3** Epicurean, **4** Synchs, **5** Rib, **6** Night, **7** Splurge, **12** Lathering, **13** see **20**, **15** Algebra, **16** Oil rig, **18** Congo, **20/13** Lewis Carroll, **22** Psi

Quick quiz #44
Answers

1 The cosmic microwave background, the afterglow of the big bang. It stands for Cosmic Background Explorer
2 CRISPR genome editing
3 Dock leaves against nettle stings
4 Perfect numbers, equal to the sum of their divisors (eg, 6 = 3 + 2 + 1)
5 Cracking

Puzzle *set by Katie Steckles*

#52 Bus change

I am about to get on the bus, but I don't have the exact money for the £1 fare. The driver doesn't give change so I hand over more than £1 and they keep the excess.

Once I have sat down, I realise that even though I didn't hand over all my coins, the amount of money I had with me was the largest possible amount I could have had in change without being able to pay £1 (or any multiple of £1) exactly. How much did I have?

Answer next week

#51 Birthday candles
Solution

If you start by blowing on one candle and work your way around the cake, blowing on each candle once, this will put out all the candles in seven puffs – and this is the fewest puffs you can do it in. The trick is to make sure each candle gets blown on an odd number of times.

Our crosswords are now solvable online
Available at newscientist.com/crosswords

Keep your distance

Feedback's time has finally come. For years we have sat in a small, dark room, shunning contact with the outside world. An elaborate system of pulleys and pigeons brings us everything we need to survive and, most importantly, produce this column.

Now, we hear on the pulley-lines that this lifestyle is encouraged by governments and healthcare professionals to help slow the spread of covid-19. So for those of you unaccustomed to a life of self isolation here are a few tips:

No. 1 **Learn to hula-hoop. This will help you maintain a distance of at least 1 metre from people at all times.**

No. 2 **Exercise at home. A bit of exercise is crucial to a sound mind. Feedback has a highly collectable set of Mr Motivator workout tapes that we couldn't live without. Other options are apparently available.**

No. 3 **Maintain regular work hours. We have always known this is crucial to a healthy work-life balance. As such, we use a version of the pomodoro technique that involves working for 25 minutes, taking a 5-minute break and then repeat. Feedback has followed this meticulously for years, and though it's hard getting your daily sleep in just 5-minute windows, you do eventually get used to it.**

School's down, not out

With many schools and colleges running classes digitally because of the coronavirus pandemic, students are having to come up with new and ingenious ways to get out of doing their homework.

In China, some 50 million students have been taught lessons via an online tool called DingTalk. According to *Technode*, the students hatched a plan to get DingTalk removed from app stores by bombarding it with one star reviews.

Unfortunately, other users countered their efforts by posting a flurry of five star reviews, and the campaign didn't succeed.

Happy bidet to you

Forget hand sanitiser and loo roll. The black market for bidets is about to go through the roof.

Bidets are those mysterious down under sinks that are easy to mistake for either a birdbath or a lidless toilet. Possibly – and we aren't looking at anyone in particular – both. According to Crunchbase, one direct-to-consumer bidet start-up saw its revenue triple after toilet paper started disappearing from shop shelves.

It's hardly surprising. Once you have overcome the fear of spraying dirty water everywhere, a bidet is simpler, more energy efficient, more hygienic and much much greener to use than scrolls of dead tree cross-section.

There are disadvantages, of course. Space, for one thing. Availability for another. Feedback rarely visits supermarkets, but we hear our local one doesn't have a bidet aisle. Not that it has a toilet paper aisle either, apparently. Now it just has a lot of Angry Person aisles and not much of anything else.

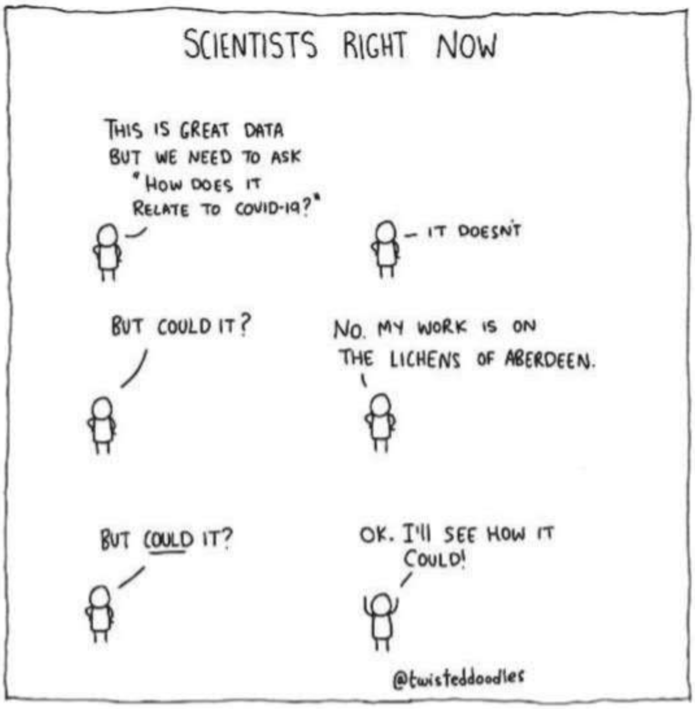
Your songs

You're so vain, you probably think this song is about you. And if it isn't, then you will probably stop listening. That, at least, is the upshot of new research by Grant Packard and Jonah Berger published in *Psychological Science*. It turns out that listeners have a marked preference for songs that make use of the second person singular in the title, as though the performer was directly addressing their fans and endowing them with a shared perspective.

These results are hardly surprising. After all, don't we all like to be noticed? To be seen? To be directly addressed? Lord knows, we get a little shiver of recognition down the spine every time a microphone malfunctions and blasts feedback out of a nearby speaker.

That is why The Beatles achieved such success with hits like *I Want To Hold Your Hand*, and bombed at the charts with dreck like *They Want To Hold His Hand*, *He Wants To Hold Their Hand* and the perennially ambiguous *Whom Wants To Hold I's Hand*.

Twisteddoodles *for New Scientist*


SCIENTISTS RIGHT NOW
THIS IS GREAT DATA BUT WE NEED TO ASK "HOW DOES IT RELATE TO COVID-19?"
– IT DOESN'T
BUT COULD IT?
NO. MY WORK IS ON THE LICHENS OF ABERDEEN.
BUT COULD IT?
OK. I'll SEE HOW IT COULD!
@twisteddoodles

In case of emergency

These are difficult times for us all and humour and levity are in short supply. Thankfully, our kind readers continue to send us examples of nominative determinism, and we have built up a healthy stockpile, saved for just such an emergency.

Ian Darby sends us a cutting from the *The Courier-Mail* of Brisbane featuring a concerned parent who has bought a job lot of loo roll, nappies and Nurofen in preparation for covid-19 shortages. Her name is Laura Spender.

Also featuring in Australian media stories about the coronavirus is the New South Wales minister for health, Brad Hazzard. Thanks to Michael Butcher for that one.

Malachy Bromham passed on a forensic psychology study by Kenneth Dodge and Cynthia Frame. Natalia Vukolova sent in the CEO of the Royal College of Pathologists of Australasia, Debra Graves. And Steve Swift wrote in to tell us of a new member of his local speedwatch – himself.

Lesley Negus wrote to us about The Porn Conversation, a non-profit that helps parents and carers talk to young people about pornography. Its founder is Erika Lust.

However, after somewhat intrepidly googling Lust, Feedback can report that Lust chose her name later in life. So this one is less a case of nominative determinism and more a case of determinative nominism.

Got a story for Feedback?

Send it to New Scientist, 25 Bedford Street, London WC2E 9ES or you can email us at **feedback@newscientist.com**

JAMES OSMOND/GETTY IMAGES

How are these stones still aligned with the sun after all this time?

This week's new questions

Mysterious alignment **How can ancient monoliths that were aligned with the sun at the equinox thousands of years ago still be lined up, given that plate tectonics moves land masses over the years?** ***Roger Bennett****, Mansfield, Nottinghamshire, UK*

Material change **What kinds of plastic are the most planet-friendly? And are biodegradable materials, such as those made from bamboo, preferable to recycled plastic, which makes use of the plastic waste that we already have?** ***Lynsey Harrison****, Leeds, UK*

Night watch

The health-tracking watch I got for Christmas claims to know when I am awake or in light, REM or deep sleep. How does it do this?

James Olver
By email, no address supplied
I have been the proud owner of a health-tracking watch for just over a fortnight, and it has become clear to me that it isn't very good at knowing whether or not I am asleep.

Several times, it has reported that my night's sleep started significantly earlier or finished significantly later than was the reality. It appears to interpret a period of low, stable heart rate, together with little or no movement, as light sleep, provided it is followed or preceded by actual sleep.

It has overestimated my period of sleep by more than 2 hours on a number of occasions. These events have happened when I have yet to go to bed, when I am in bed but have yet to fall asleep, when I have woken at night and been unable to get back to sleep, and even when I have got up but then sat quietly for some time.

A major reason for buying the device was to monitor my sleep in an effort to improve my very poor sleep patterns. My initial impression after two weeks is that it isn't fit for purpose.

Rowan Hooper
London, UK
I looked into this for the chapter on sleep in my book *Superhuman: Life at the extremes of mental and physical ability*. I spent the night in a sleep lab wired up to an electroencephalograph (EEG), which directly measures brain waves, but I was also wearing a sleep tracker.

The sleep tracker, like most on the market, measured heart rate and movement. The idea is that because, for example, the heart slows as you move into stage 2 (deep sleep) of our four-stage sleep cycles, and the body is paralysed during REM sleep, the tracker can estimate the stage you are in.

The EEG, however, measures brain waves, so it can categorically show the stage of sleep you are in. The picture the sleep tracker provided of my sleep cycle wasn't the same as the very accurate picture that came from the EEG.

In other words, sleep trackers guesstimate the stage, and might be less reliable than direct measurement with EEG. If they can help you improve the quality of your sleep, great. If they add to the anxiety over the quality of sleep you think you are getting, perhaps not so good.

Allan Angus
via Twitter
I have used a sleep tracker for around five years. Subjectively, I would say its results correlate well with my feelings of being well rested or not. Over the years, it has also collected data that indicate an improvement after my kids stopped needing a ride to school in the morning.

Seat of wisdom

Have we always known that we think with our heads? Is it instinctive?

Hazel Russman
London, UK
We haven't always believed that we think with our heads. The ancient Egyptians had such a poor opinion of the brain that, during the process of mummification, they removed it through the nostrils and threw it away.

In ancient times, Jews associated each mental function with a different part of the body. Emotion was located in the bowels, willpower in the heart and intellect apparently in the kidneys. Thus, in literal translations of the Bible, Psalm 16, verse 7 says: "I will bless the Lord who has given me counsel. My kidneys instruct me in the night season."

Peter Urben
Kenilworth, Warwickshire, UK
Sceptics, and those of like kidney, know in their heart that many mental attitudes and activities are linguistically attributed to organs far from the head. Some of the examples we can put a finger on are purely metaphorical, but many must reflect an earlier view of physiology.

Spencer Weart
Hastings-on-Hudson, New York, US
Brain trauma – as many warriors must have noticed since ancient times – can cause cognitive disorders. In particular, a blow to the head, far more than anywhere else, can render us unconscious.

So, naturally, the acute observer Aristotle, and his academic followers for some two millennia, concluded that the brain is an organ to cool the blood, and the seat of intelligence is the heart… wait, what?

Eric Kvaalen
Les Essarts-le-Roi, France
In the Bible, there is no mention of the brain, or of thoughts being in the head. Instead, thoughts and emotions were considered to be associated with the heart (for instance, Deuteronomy, chapter 6, verse 5), the liver (Lamentations 2:11 and the original text of Psalm 16:9), the bowels (Psalm 40:8) and even the kidneys (Psalm 26:2). Some translations don't bear this out though. ▮

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Nietzsche
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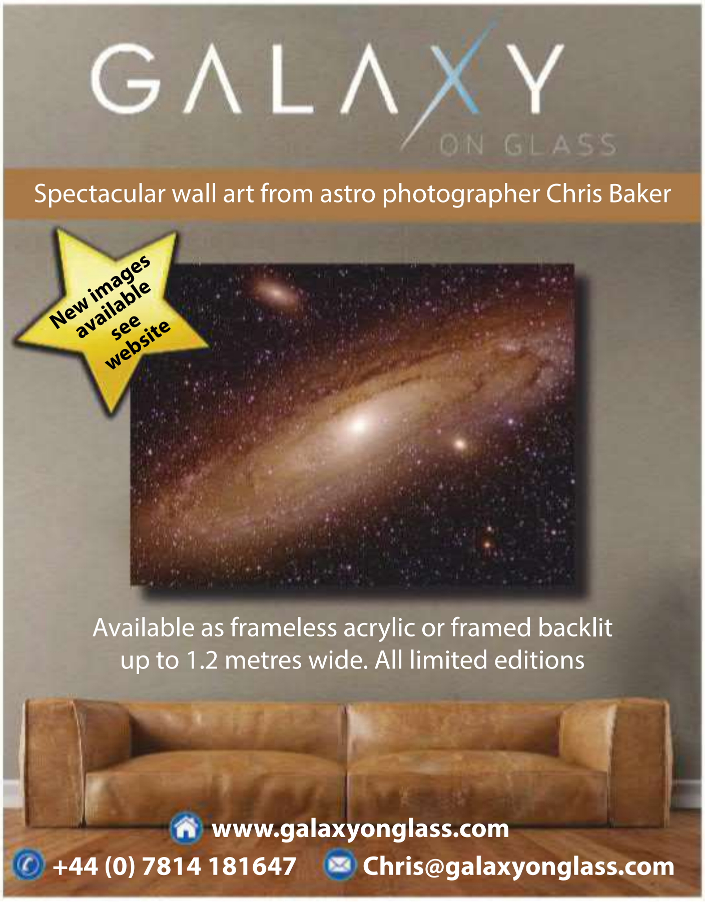

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Victorian corpse displays sparked **John Troyer**'s interest in how humans use technology around dead bodies. He explores our fascination with death and its impact on life

So, what do you do?

I am director of the Centre for Death and Society, one of the world's only interdisciplinary research centres to study the links between death, dying and the dead body. My research focuses on the relationships between the dead body and technology, science and bioethics. My younger sister called me the Overlord of Death.

How did you end up working in this field?

I'm the son of a funeral director but that isn't really why I do what I do. At university, I took a seminar on pre-second world war cinema and spectacle. I ended up studying late 19th-century human corpse displays (which happened quite a bit) and wondered if those bodies were embalmed. I asked my dad for his embalming textbooks and that's when I discovered my PhD dissertation: how human technologies such as embalming, photography and even museum displays altered how the dead body appeared. I went to a conference on the subject and I knew then that I'd found my people: the Death, Dying and Dead Body People.

Can you tell us about your new book?

Technologies of the Human Corpse is about how humans use tools and technologies to transform the dead body into something new, such as a consumer product or a museum display. I look at how the social stigma of AIDS transformed dead bodies into something terrifying, the politics of detainee deaths in Guantanamo Bay, those sorts of things.

The book is quite personal, too. Why is that?

It's also part memoir. My younger sister Julie died on 29 July 2018 from brain cancer. She was 43. I reflect on watching her die throughout the book.

What are you working on right now?

I'm looking at all the government commissions that have studied death and dying. It's amazing how many say that we are using technology to alter the human experience of mortality and increasingly expect the technology to always be present and available. I've also been reflecting on the commissions in the 1990s that looked at the AIDS pandemic. Their aim was to make sure public health systems wouldn't fail people infected with a life-threatening virus in future. Here we are with coronavirus and all kinds of work has been done on large-scale public health support but so much of it seems forgotten or sadly shelved.

How has your field of study changed in the time you have been working in it?

Death studies as a field has more visibility now, but death has always been accessible as a subject of study. We humans keep dying; keep producing dead bodies. We keep discussing death.

> "Here we are with coronavirus and all kinds of work done on public health support seems forgotten"

If you could send a message back to yourself as a kid, what would you say?

Don't worry about being fat (I was an overweight kid) – it will all work out in the end.

What's the best thing you've read or seen in the past 12 months?

Radiolab's podcast about Dolly Parton, *Dolly Parton's America*, was phenomenal. *Aniara*, an existential Swedish sci-fi film, was also really good.

If you could have a conversation with any scientist, living or dead, who would it be?

The mathematician Norbert Wiener, about his work in cybernetics and what he'd think of today's ultra-rapid computing machines.

Do you have an unexpected hobby, and if so, please will you tell us about it?

I've really got into weightlifting. I dropped it after my sister died but picked it back up this summer.

How useful will your skills be after the apocalypse?

I know how to handle all the dead bodies. Death wins. Death always wins.

OK, one last thing: tell us something that will blow our minds...

In grad school, I took Intro to Modern Dance and decided that I needed to start a company called Big and Tall Men Modern Dancing. I still plan on making this happen. ▮

John Troyer is director of the Centre for Death and Society at the University of Bath, UK. *Technologies of the Human Corpse* is out in April (MIT Press)

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